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THE BLACK ROT DISEASE OF GRAPES

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THE BLACK ROT DISEASE OF GRAPES.*

HOST PLANTS

Consideration of the origin, evolution, distribution, and methods of care and cultivation of the plants affected by a specific disease is often of assistance in reaching conclusions as to the origin and history of the disease as well as its possible distribution and economic importance. In few cases is the information on this phase of the subject in such accessible form as in the case of the crop affected by the Black Rot. So far as known, the Black Rot is confined to members of the family Vitaceae and becomes of economic importance only on cultivated varieties of the genus *Vitis*. For New York, and, in fact, for American conditions generally, except the South and extreme West, we are concerned with the development only of those species of the grape indigenous to North America. A most satisfactory account of the evolution of our commercial varieties of grapes is found in Bailey's "The Evolution of Our Native Fruits" ('98), in which 126 pages are devoted to "the rise of the American grape." This author states (l. c. 117) "that no less than a hundred books have been published in this country on the grape." This does not include a monograph by Hedrick ('08) in which is an excellent historical account of the American grape and the grape industry.

From these sources, we learn that after repeated attempts it was found, relatively early in the history of American viticulture, that the European grape (*Vitis vinifera*) could not be grown successfully in our northern latitudes since the vine was not hardy nor vigorous enough to withstand our cold winters nor the attacks of insect pests and fungous diseases. Attention was then turned to American species as a source of stock, and at the present time our four most important commercial varieties are derivatives of our native wild species. These varieties are Concord, Niagara, Catawba and Delaware. The latter is thought to be part *vinifera*, as might be inferred from the fact that it is more subject to Mildew and Phylloxera than the others.

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*Also presented before the Faculty of Cornell University May 28, 1909, as a major thesis in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

('98) Bailey, L. H. Sketch of the Evolution of our Native Fruits. The Macmillan Company. London, 1898, xiii and 1–472.

('08) Hedrick, U. P. The Grapes of New York. Rept. N. Y. (Genéva) Agr. Exp. Sta. 1907, Part II: 1–564. 1908. Published by the State of New York as Ann. Rept. Dept. Agr. 15: Vol. 3, Part II.

From the above facts we would be led to expect in our American vines a more resistant and hardier stock, since they are removed only a short distance from ancestors that have grown up with and are able to withstand, to a certain extent at least, the invasions and depredations of native pests and fungous disorders. However, under cultivation and artificial propagation, and especially because of the aggregation of a large number of vines in a vineyard, many more opportunities are offered for the increased propagation and wider dissemination of insects and fungous enemies.

ECONOMIC IMPORTANCE OF THE GRAPE INDUSTRY

Notwithstanding the relatively restricted localities in which grapes can be grown in the State of New York, the industry is of considerable economic importance. Figures are of interest in this connection. In the census report for 1900, we find that New York ranks second only to California in the total value of the grape crop. The California conditions are such that it is possible to grow the viniferous varieties there, consequently the production of wine and raisins is very large, in addition to the large number of grapes grown for eating out of hand. In New York, the total value of the grape crop in 1900, including the then relatively small amount of juice produced, was $2,763,711. The following table, taken from the same source, shows the relative value of the grape and other crops:

Hay and forage crops,	$55,237,446
Corn,	20,024,850
Potatoes,	15,019,135
Oats,	12,929,092
Wheat,	7,332,597
All orchard products, including apples, apricots, cherries, peaches, pears, plums and prunes,	10,542,272
All forest,	7,621,108
Grape,	2,763,711
Tobacco,	1,172,236

Unfortunately, statistics regarding the value of the various orchard products are not made separately, but it is evident that grape raising is one of the important fruit industries of the State. The Chautauqua grape belt alone in western New York is estimated to cover 30,000 acres at the present time, and according to Prof. Hedrick (l. c. 78), the present acreage of the State is not less than 50,000 acres.

NEW YORK STATE GRAPE REGIONS

Since frequent reference will be made to the various grape districts of New York, it may not be out of place at this point to define these regions a little more definitely. A description of the four districts of the State is given by Hedrick, together with a history of the rise of the industry in each section. Dorsey ('09) has put this data in more accessible form.

In point of time, the Hudson River valley region is the oldest. The production of the Concord in this locality outstrips that of any other variety, while the Delaware stands second. Yet this region is often referred to as the Delaware region. It is practically confined to the four counties of Ulster, Columbia, Orange, and Dutchess.

The second region, known as the Central Lake region, is not so definitely located. It includes areas bordering on Keuka, Canandaigua, Seneca, and Cayuga lakes, and is located in the following counties: Ontario, Yates, Schuyler, Steuben, and Seneca. Catawbas and Delawares are grown extensively in the section and grape-growers often refer to it as the Keuka Lake or Catawba region.

The Chautauqua belt is the most distinct of any of the grape regions. The Concord is the predominating and almost exclusive variety. As this variety was not introduced into Chautauqua county until 1856, the remarkable development of the region is worthy of note. The belt now extends the whole length of that county and a part of Erie county, and extends back from the lake front for a distance of three to five miles.

The most recent belt is the Niagara. It lies along the Niagara river and the shore of Lake Ontario. The following counties are included: Niagara, Orleans, Monroe, and Wayne.

THE DISEASE

HISTORY

This disease has been known in America for many years as the "Black Rot." This name was given to distinguish it from the gray or brown rot caused by the mildews, etc. When the disease was introduced into France, the English name was carried over, and from there it has spread into Germany, Italy, Asia Minor, and elsewhere. Locally, and owing to mistaken identity, it is sometimes referred to as Bird's Eye and as Apple Rot, thus being confused with Anthracnose.

('09) Dorsey, M. J. The Grape Districts of New York and Table of Varieties. N. Y. (Geneva) Agr. Exp. Sta. Bul. 315: 133–161. 1909.

On the occasion of his visit to the Dufour vineyards near Lexington, Ky., while on his second visit to America, Francois Andre Michaux writes in his travels (1805): "But his (Dufour's) success is not equal to his attention — the fruit always rots before it arrives at maturity. When I saw them, the bunches were few and stunted, the grapes small, and everything appeared as though the vintage of the year 1802 would not be more abundant than those of the preceding years."

From the descriptions of various of the pioneers in the American grape industry, there seems to be no doubt that the foliage and part of the fruit was often destroyed by the Downy Mildew (*Plasmopara viticola*), and also that many of the clusters had a different kind of disease which we are able to recognize from descriptions as the Black Rot. Such diseases were unknown to the Old World vine-growing districts, and there seems to be no question that both the Mildew and Black Rot are indigenous to America. The native vines have for ages been attacked by these diseases, so that by a selective process only the most resistant remain. The less resistant viniferous varieties never having experienced such attacks were not able to withstand the Mildew, Black Rot, and Phylloxera, and consequently succumbed. That this is the case is attested also by the wide-spread ravages of these fungous pests on their introduction into Europe. Thus, the early American attempts in viticulture with the European vine were failures, and it was only when the ameliorated American vines were used that the grape industry in this country was placed on a firm basis. The dissemination of the disease to the various new vineyards of the country was a very easy matter, for these early vineyardists were anxious to obtain the very best varieties, and they not only went to the wilds themselves to look for desirable kinds, but also asked publicly that persons send them cuttings. Longworth made such a request in the columns of the Cincinnati Gazette in 1848 or 1849, according to Bailey (l. c. 67).

Dufour, as early as 1804, and Longworth, about 1848, encountered losses which were so serious as to make the business unprofitable and their vineyards were abandoned, and this too without their knowing what the real trouble was. Longworth and his followers were using extensively the new American vine, Catawba, but even this variety under vineyard conditions was unable to withstand completely the attacks of fungi and insects.

With the rise of the grape industry about St. Louis, the Black Rot also became prevalent there, and in 1860 to 1864 was epidemic.

(1805) Michaux, F. A. Travels in America, Second Journey. London, 1805.

After more than fifty years of grape culture we have the first scientific inquiry into the nature and cause of the rotting of the fruit. In September, 1861, Dr. Geo. Engelmann ('61) read a paper before the St. Louis Academy of Science, in which he clearly describes the two most serious grape diseases. These are easily recognized as Downy Mildew and Black Rot. The Journal of Proceedings reads as follows: "Dr. Engelmann exhibited specimens and numerous drawings of two species of fungi, which infest our vineyards to such an extent as to materially diminish the crop and influence the culture of the grape, at least that of the Catawba, in our region." Dr. Engelmann's description is as follows: "The second kind of rot — the black rot — is brought on by a very different kind of fungus, which I believe to be undescribed by botanists. It evidently belongs near Ehrenberg's genus and ought to bear the name *ampelicida*. It makes its appearance only on nearly full grown berries, exhibiting in the first stage a discolored spot on the side, but never at the base of the berry, about two lines in diameter, with a dark spot in the centre. This spot soon becomes light brown and remains so, while the surrounding part of the berry gets darker and exhibits a rough or (under the magnifier) pustulous surface; gradually, now, the berry shrivels up and turns black. The individual fungi are little spherical bodies," etc.

Fifteen years later, the same author ('76) read before the same society a description of a leaf spot of grapes which we can easily recognize as the leaf stage of the Black Rot. This reads as follows: "I exhibit to you, today, another grape fungus which is new to me, and seems to have been unknown to those grape growers with whom I have conversed. A yellowish-brown spot, a few lines in diameter, appears on the leaf, on the upper side of which, a good eye, or a glass, will discover a number of very minute black specks. These are little globules .13–.15 line in diameter, which have a little opening at the top from which they emit their microscopical spores by the thousand."

Little note seems to have been taken of these two publications by Engelmann until a relatively recent date. This doubtless was due to the fact that, scientifically, the Journal had a limited distribution and, practically, that the papers were not accompanied by any suggestions as to means of control. At any rate, it was not until the introduction of the Black Rot disease into the vine-growing regions of France that a serious and extended study was made of the cause of this disease with means of control.

('61) Engelmann, Geo. "Two species of fungi which infest our vineyards." Trans. St. Louis Acad. Sci., Jour. Proc. 2: 165. 1861.

('76) Engelmann, Geo. Oak and Grape Fungi. Trans. St. Louis Acad. Sci., Jour. Proc. 3: ccxv-ccxvi. (1876). 1877.

In August, 1885, berries attacked by Black Rot were sent to the National School of Agriculture at Montpellier, France, by M. Ricard, steward of an estate near the town of Ganges. There, Professors Viala and Ravaz recognized the disease as Black Rot. Immediate measures were taken to exterminate the disease.[1] In 1886, there was very little Black Rot owing to the dry weather, but the disease was found sparingly in other localities. In 1887, rot was very serious in many new localities, so it seems quite likely that the Black Rot had been in France to a limited extent for several years prior to 1885, the date of its discovery there. It probably gained an easy entrance into France on the American stock that was imported on which to graft European vines as a means of combatting the Phylloxera.

The first elaborate and well-illustrated account of the Black Rot disease was made by Professors Viala and Ravaz ('86). In June, 1887, Professor Viala was detailed by the French government to visit America in the interest of French viticulture. A period of six months was given to the investigation and in company with F. Lamson Scribner, of the United States Department of Agriculture, all the large grape-growing regions in the States were visited. As a result of this trip, a bulletin was published from the United States Department of Agriculture, by these gentlemen ('88), and the year following there appeared a volume from Professor Viala ('89) on the subject. Since that time these two gentlemen, as well as many others, both in United States and Europe, have made frequent contributions both to the nature of the parasite and to means of prevention or control.

GEOGRAPHICAL DISTRIBUTION

It is a relatively easy matter to obtain information on the spread and present distribution of the Black Rot disease. This can be done quite accurately by making a bibliography of the literature relating to the disease. From examination of such literature one can see that after the introduction of the malady into France, it very rapidly spread to adjacent vine-growing regions, then to Germany, Italy, and Asia Minor. At the present time, practically no vine-growing section is entirely free from the disease, with the one exception of California in

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('86) Viala, P. et Ravaz, L., Mémoire sur une nouvelle maladie de la vigne, le Black Rot (Pourriture noir). Ann. l'École Nat. Agr. Montpellier 2: 17–58. 1886. Also published separately. Bibliothèque du Prog. Agr. et Vit. 1886: 1–62. 4 plates.

('88) Scribner, F. L., and Viala, P., Black Rot. U. S. Dept. Agr., Bot. Div., Sec. Veg. Path. Bul. 7: 1–29. 1888. 1 plate.

('89) Viala, P. Une Mission Viticole en Amérique. Montpellier and Paris. 1889. 387 pages and 8 chromolithographs.

western United States. McAlpine and Robinson ('98 (?)) state that Massee has reported it from Victoria in 1893, but that they have never found it. The date of their publication is approximately 1898, as can be gathered from literature cited.

Some * have predicted that California vines would eventually succumb, but this is not at all certain since the weather conditions there are very different and are probably such as entirely to prevent the perpetuation of the parasite even if introduced. The writer is inclined strongly to the latter view, since it does not seem possible that with the importation of grape stock from the East there should not have been carried over an occasional source of infection.

ECONOMIC IMPORTANCE

All writers are agreed that Black Rot is the most serious fungous malady with which the vineyardist has to contend. The Phylloxera has been overcome to a great extent, while neither Downy nor Powdery Mildew are as difficult to control. Data on this point are so evident and so general in Experiment Station literature that it will be sufficient to give only a few generalities.

It has been recognized, generally, that Black Rot varies with the season, there being an abundance of it in wet seasons and much less in dry ones. Also, that the rot is more serious in the warm and humid regions than it is in cool and drier regions. Thus, in North Carolina the entire crop may be lost within a week after blossoming time, while in New York the greatest losses come when the berry is one-half to two-thirds grown. Scribner ('90) believed that Black Rot "did not attain the same vigor of development in the northern grape-growing regions that it did farther to the south." But even if that be true, New York vineyardists all know that in some years the conditions could not be worse farther south.

Beginning in 1903 and continuing with increasing vigor up to 1907, Black Rot became so destructive in both the Niagara and Central Lake regions that the entire crop in many vineyards was often lost. In 1906, in a large vineyard of 200 acres at Romulus, N. Y., not enough grapes were saved to pay for operating expenses, and this in spite of the

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*Scribner, F. Lamson New Observations on the Fungus of Black Rot of Grapes. Proc. Soc. Prom. Agr. Sci. 9: 68–72. 1888.

('90) Scribner, F. Lamson. Report on the Extent, Severity, and Treatment of Black Rot and Brown Rot in Northern Ohio in 1889. U. S. D. A., Sec. Veg. Path. Bul. 11: l. c. 77. 1890.

'98 (?) McAlpine, D. and Robinson, G. H. Additions to the Fungi on the vine in Australia, Dept. Agr. Victoria. 80 pp. No date.

fact that the owners sprayed until the middle of July and, as they believe, did thorough work. In 1907, there was very much less rot owing to the dry season. This was general in all grape-growing sections. In 1908, the only region which seems to have been seriously affected was that of the Central Lakes, and even in this it was restricted to certain localities. In general the season was very dry, but in a few localities about the lakes there was an abundance of rain * and losses in unsprayed vineyards were as high as seventy-five to eighty per cent. In fact, in some vineyards there was so much rot that it did not prove profitable to glean out the good clusters.

In spite of the fact that Black Rot has not been serious in most of the grape-growing sections of New York the past two years, the writer has never had difficulty in finding an occasional berry destroyed by the Black Rot fungus, even in well-kept vineyards in the heart of the Chautauqua belt. This belt is decidedly the most free from rot of any of the sections. These facts would seem to indicate that the rot may at any time become an important factor again, depending on the advent of a season favorable for its development.

Epidemics of this disease affect economic conditions only in the locality in which the grapes are grown. Grapes are regarded more or less as a luxury and the lack of grapes does not have the same general effect as the lack of wheat or of potatoes.

SIGNS OR SYMPTOMS

The general signs or symptoms of this disease have been described at various times in the horticultural papers, but the first accurate, scientific description is that of Engelmann. The descriptions are sufficiently clear as to leave no doubt concerning the identity of the disease. All green parts of the vine may be attacked, but the old parts never are. Julien ('97) states that in Nivernais, France, only the fruit is attacked. Stevens and Hall ('09) also note the fact that the fruit of Scuppernong and other *rotundifolia* varieties of southern United States is rarely attacked.

On the leaves (Fig. 131.)

Some time in June or early in July, Black Rot appears on the leaves in the form of reddish brown, more or less circular spots. The first evidence of the spot is the slight blanching of a single one of the smaller

(*) See meteorological data on page 347.

('97) Julien, Ch. Sur le développement du Black Rot de la Vigne dans le Nivernais. Bul. Soc. Myc. France, 13: 73–75. 1897.

('09) Stevens, F. L., and Hall, J. G. Notes on Plant Diseases Occurring in North Carolina. Ann. Rept. N. C. Agr. Exp. Sta. 21: l. c. 74. 1909.

areola of the leaf. Soon the blanching extends to adjacent areolae, and if an areola is entered it is usually entirely involved. The spread of the

FIG. 131.—*Black Rot lesions on leaf of Niagara grape. (Natural size.). Photo June 27, 1908.*

spot is concentric but not perfectly circular. The small veinlets form the margin of the spot so that the outline is finely crenulate. By the time the spot is .3 to .4 mm. in diameter, it has a cinereous appearance.

At this early stage the margin, while sharply defined, is not changed in color. By the time the spot is 1 mm. in diameter, the margin appears as a black line, while the remainder of the spot is grayish brown. A little later the margin is a brownish band and the brown gradually extends inward until the whole spot is covered. As soon as the brown band attains some width the blackish line on the margin is to be seen

FIG. 132.—*Black Rot lesions on stems, petioles, leaf veins, and tendrils of Niagara grape.* (*Natural size.*) *Photo. June 8, 1907.*

again. A second wave of deeper brown may pass across the spot but sometimes it does not get entirely across and thus leaves a marginal band of a deeper brown than the central disc. Spots vary in size from 1 mm. up to 8 mm. in diameter, but in general are 3 to 5 mm. On the European vine, Viala ('89) records the diameter of spots as 4 to 5 cm. or larger. Occasionally the whole leaf is destroyed but this

('89) Viala, P. Une Mission Viticole en Amérique. Montpellier, 1889, l. c. 239.

is by the coalescence of many spots. When the spot has attained full size, black bodies, pycnidia (Plate II, Fig. 9), protrude from under the cuticle and either dot the entire surface of the spot with minute specks or are more often confined to a more or less concentric ring. The different shades of color are apparent on the under side of the leaf on such varieties as have leaves which are smooth beneath. The pycnidia, however, have never been seen on the under side of the leaf in our varieties. Viala and Ravaz ('88) show that the leaf spots of the various varieties are really all caused by the same fungus, and also state that in 1886 (l. c. 490, foot note 2) they first called attention to the fact that the leaf spots were connected with the Black Rot disease.

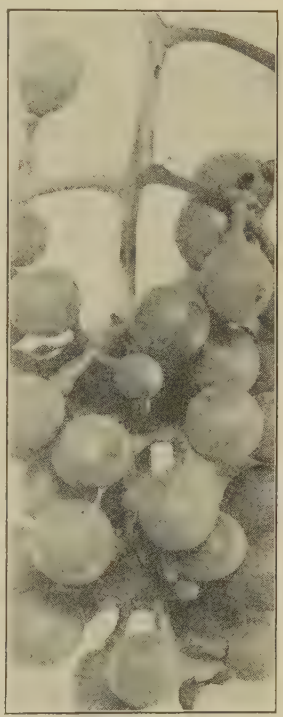

FIG. 133.—*Black Rot lesions on peduncle of cluster. Near the center the remnant of an infested pedicle can be seen. This infection occurred before the blossoms opened.* (*Natural size.*) *Photo. July* 15, 1909, *C. N. Jensen.*

On stems, tendrils, peduncles, petioles and leaf veins (Figs. 132 and 133.)

The character of the Black Rot lesions on stems is somewhat different from that on leaves. Its first appearance is a small darkened depression which soon becomes very black. On a cane the lesion rarely extends more than a quarter of the way round, while on a tendril or leaf petiole it may extend from half to all of the way round. The length of the lesions vary from 2 mm. up to 2 cm., while in form they may vary from circular to elliptical or very much elongated. On shoots, the lesions never extend so deep as to cut off the sap supply, but on leaf petioles this occasionally happens, rarely so on peduncles, and quite commonly so on pedicles and tendrils.

On the berries (Figs. 134, 135, 136, 137.)

The first indication of Black Rot on the berry is the appearance at some point of a small circular blanched spot. The spot is scarcely 1 mm. in diameter, and when of this size the blanching is so slight as to be detected only by careful observation. It rapidly becomes more apparent and has a whitish appearance. Even yet the contrast is not

('88) Viala, P. et Ravaz, L. Note sur le Black Rot (Laestadia bidwellii) Prog. Agr. et Vit. 9:490–493. 1er semestre.

great, but it becomes more apparent by the appearance of a brownish line at the margin. The whitish centre increases in size and the brownish or reddish brown ring increases in diameter as well as in width and is quite evident when the spot is 2 mm. in diameter. When the spot is 3 mm. in diameter the ring is one-half mm. in width and enough darker to give a bird's eye effect (a light circular disc with an encircling darker band). The spot rapidly increases in size so that in twelve hours more it may be 6 to 8 mm. in diameter, and the encircling band nearly 2 mm. in width. After five hours more, the spot is 8 or 9 mm. in diameter and there begins to appear an outer darker band and an inner lighter brown one which have in some cases a much lighter line between them. The aureole is thus composed of two or three bands or rings. Eighteen hours later the spot is 1 cm. or more in diameter, is distinctly flattened,

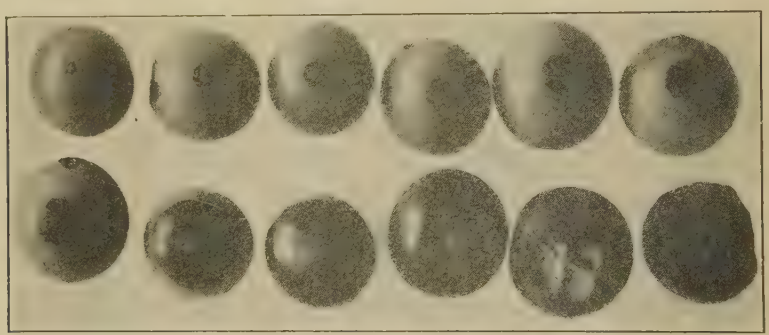

FIG. 134.—*Black Rot on berries of Niagara grape. Successive stages in the destruction of the berry. (Natural size.) Photo. July* 1, 1908.

and numerous minute brown specks appear on the white centre of the spot. In five hours more they are so numerous as to give a blackish appearance.

The spot may not become any larger in size than this and in a few days more forms a thin black superficial crust on the cheek of the berry. (Fig. 137.) Usually, however, it increases in size until the whole berry is involved. At about the same time that the blackening appears, the berry begins to shrivel perceptibly, and this continues until at the end of a week or ten days the berry is a hard, shriveled, and wrinkled mummy. Viala ('89) has noted the superficial lesion and Prunet ('98) has figured it. Such lesions have been seen on berries of several varieties, and they are of common occurrence on the Agawam and Lindley.

('89) Viala, P. Une Mission Viticole en Amérique. l. c. p. 241.
('98) Prunet, A. Observations et expériences sur le Black Rot. Rev. Vit. 9: l. c. 536 and 656. 1898.

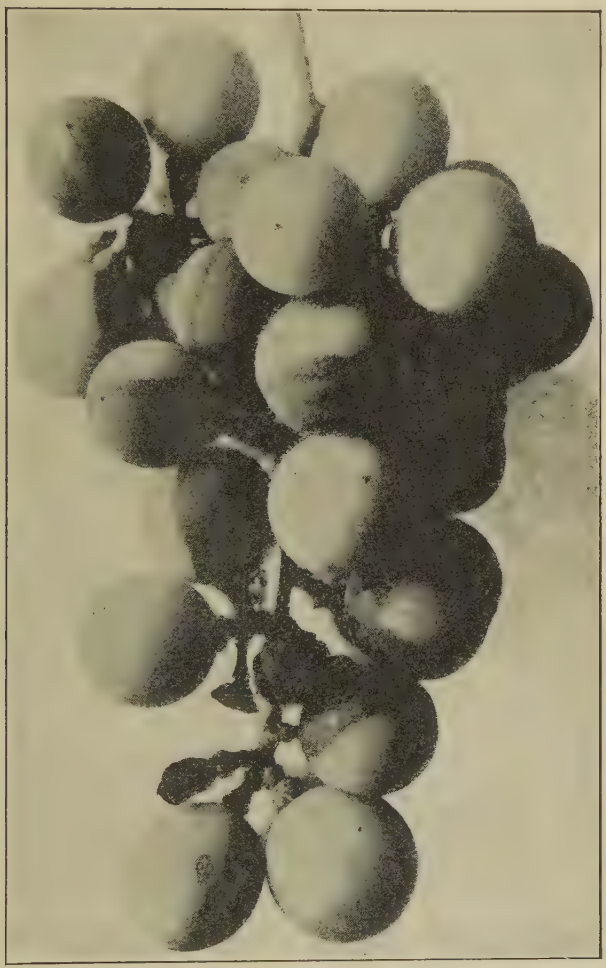

FIG. 135.—*Black Rot in Niagara cluster. A few berries rotted by an early infection; most of them just turning brown from recent infections. The berry at the top on the left shows a spot not more than 12 hours old. (Natural size.) Photo. Aug. 1, 1908.*

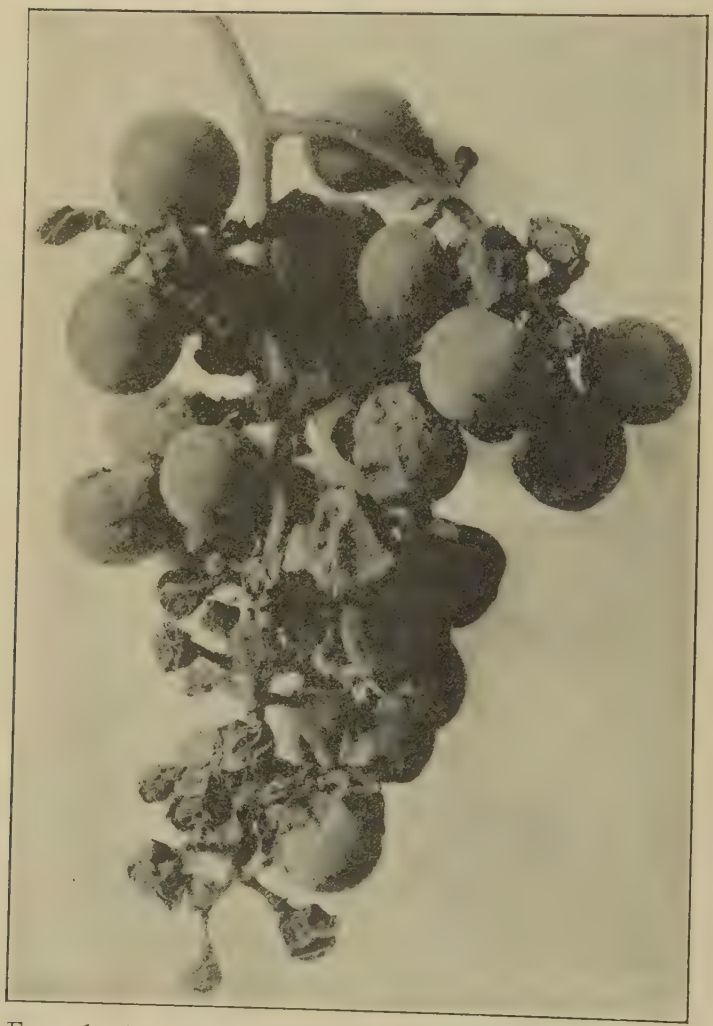

FIG. 136.—*Black Rot on fruit of Niagara grape. Every berry in the cluster is infected. Cluster shows most of the infections of the season. The pycnidia show particularly well. (Natural size.) Photo. Aug.* 1, 1908.

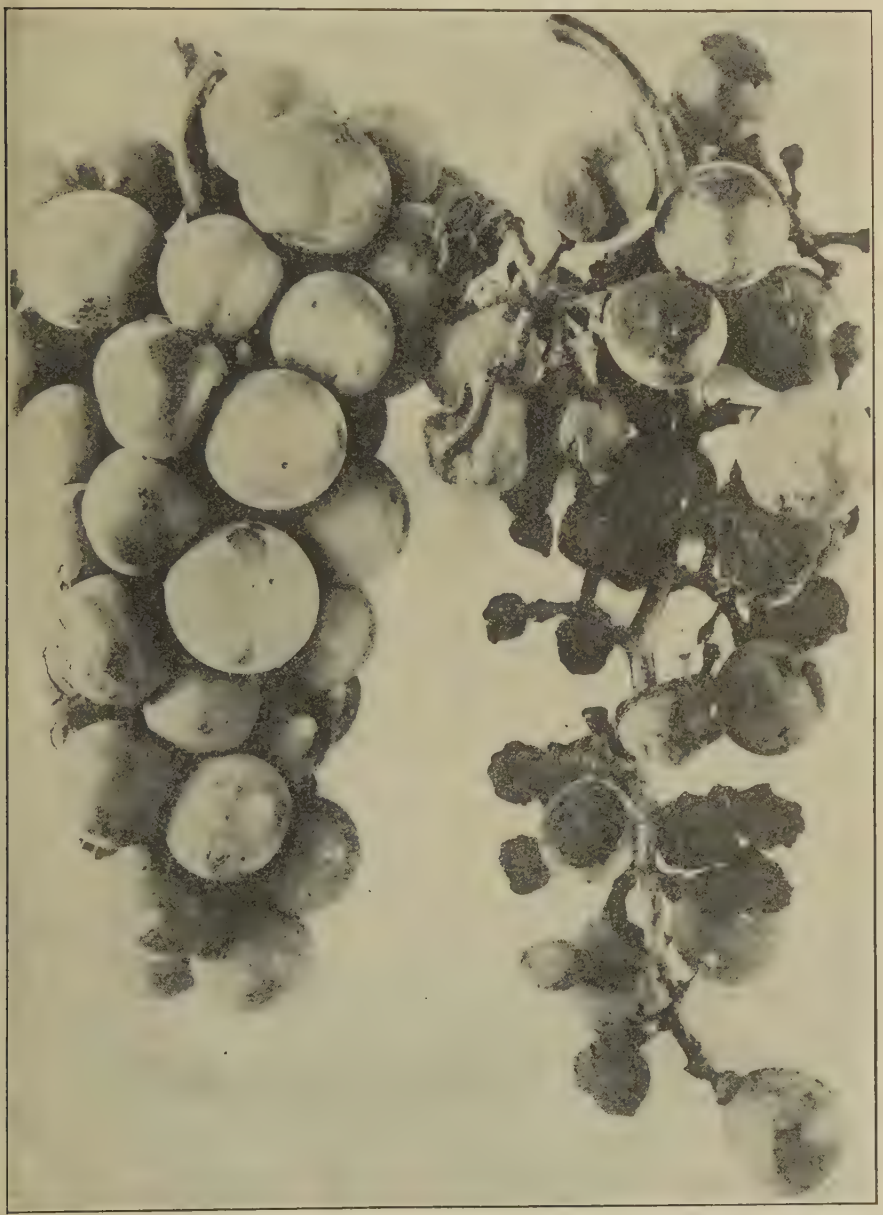

FIG. 137.— *Black Rot on fruit of Niagara grape. Shows (on the right) the various infections of the season. Nearly every berry in the cluster to the left is infected. Some are wrinkled while others are just beginning to show spots or are wrinkling from the inner side. On the right some of the superficial black crusts can be seen. (Natural size.) Photo. Aug.* 15, 1907.

ETIOLOGY

Name of the parasite

This disease is caused by the fungous parasite *Guignardia bidwellii* (Ellis) Viala et Ravaz. Other specific and generic names have been given to the organism, as will be noted from the synonymy. This is due, in part, to the polymorphic nature of the fungus, to a lack of uniformity of various mycologists in the system of nomenclature, as well as to difference of opinion regarding the structure and interpretation of parts of the fruiting bodies. According to the code of nomenclature adopted at the Brussels International Botanical Congress, the above name seems to be the correct one to apply to the Black Rot fungus. The writer has had no opportunity to examine type material of any of the forms concerned, and the following brief review of synonymy is made from an examination of the literature.

The first description of the fungus seems to be that of Dr. Engelmann ('61). This was based on the spermogonia of the fungus. In case the first specific name applied to any stage of the fungus were retained, "*ampelicida*" would seem to be the correct specific name as pointed out by Roze ('98). The date 1850, sometimes cited for Phoma uvicola B & C, a pycnidial stage of the fungus, is incorrect; it should be 1873. Material was collected by Curtis in 1850 and was sent to Berkeley, who described it in Grevillea ('73), twenty-three years later, thus giving Engelmann's description twelve years priority.

The ascosporous or perfect stage of the fungus was discovered by Dr. Bidwell, and was named in his honor, by Mr. J. B. Ellis ('80), *Sphaeria bidwellii*. According to the Brussels code the first specific name applied to the perfect stage of an organism shall be the name of the species, in which case "*bidwellii*" is the only specific name that can be applied to the Black Rot organism.

Saccardo ('82) transferred the Black Rot fungus to the genus *Physalospora,* thus placing it in a genus characterized as having paraphyses, while in his description of *P. bidwellii* he writes, "paraphysibus nullis," and then, "Hab. in baccis Vitis socia *Phoma uvicola,* quae forte eius

('61) Engelmann, Geo. Trans. St. Louis Acad. Sci. Jour. Proc. 2: 165. 1861.
('73) Berkeley, J. M. Notices of North American Fungi. Grevillea 2: 82 1873.
('80) Ellis, J. B. A new Sphaeria on Grapes. Bul. Torr. Bot. Club 7: 90. 1880.
('82) Saccardo, P. A. Sylloge Fungorum. 1: 441. 1882.
('98) Roze, E. Quel est le nome scientifique à donner au Black Rot? Bul. Soc. Myc. France 14: 24–26. 1898.

spermogonium; Vineland, New Jersey. America boreali (Bidwell)—An *Laestadia?*" A few years later, Viala et Ravaz ('88) in a short note transferred the fungus to the genus *Laestadia,* erected by Auerswald ('69). The same authors ('92) substitute the name *Guignardia* for the species of *Laestadia,* since the latter name is preoccupied by a composite genus of Kunth ('32).

Apparently the name of the Black Rot fungus should be *Guignardia bidwellii* (Ellis) Viala et Ravaz. But there seems to be some doubt concerning the validity of the generic name *Guignardia.* Magnus ('93) ('94) points out that Dr. O. Kuntze recognized the fact that *Laestadia* as applied to a fungus is a synonym and substituted the generic name *Carlia* of Rabenhorst 1857 for the species of *Laestadia.* Kuntze ('91) says* (free translation) "the composite genus *Laestadia,* Lessing, is valid, so that the homonym of Auerswald becomes a synonym; moreover, *Carlia* Rabh. is at all events older and on that account should be restored. The type is *Carlia oxalidis* Rab. (*Laestadia ox.* Sacc.) Bonorden named it correctly."

He then transferred all of the listed species of *Laestadia* in Saccardo's Sylloge to the genus *Carlia.* Also, Saccardo (l. c. Vol. II, p. 289) in a foot-note says: "Magnus in Oesterr. bot. Zeitschr. 1894, no. 6 contends strongly and not without grounds that the name *Carlia,* Bonorden 1864 (not Rabenhorst 1857), has the right of priority over *Laestadia* Auerswald 1869 (not Lessing 1832)."

But concerning the validity of the name *Carlia* there seems to be some doubt. Lindau ('97) in a foot-note states that *Carlia* of Rabenhorst

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*"*Carlia* Rabh. (1857) herb. viv. myc., ed. nov., cent. VI, Nr. 567 (cfr. Flora 1857, p. 382.) Laestadia Awd. 1869 non Less. "Kth." 1832. Die Composite Laestadia Less. gilt, so dass das Homonym von Auerswald synonym wird; auserdem ist Carlia Rbh. so wie so älter und deshalb zu restauriren. Der Typus ist Carlia Oxalidis Rbh. (Laestadia ox. Sacc.)."

('32) Kunth. Lessing's Synopsis Generum Compositarum p. 203. 1832.

('69) Auerswald. Laestadia, nov. Perisporiacearum genus. Hedwigia 8: 177. 1869.

('88) Viala, P. et Ravaz, L. Note sur le Black Rot. Prog. Agr. et Vit. 9: 490–493. 1888. 1er semestre.

('91) Kuntze, O. Reviso Generum Plantarum. Pars. II: 846. 1891.

('92) Viala, P. et Ravaz, L. Sur la denomination botanique du Black Rot. Bul. Soc. Myc. France, 8: 63. 1892.

('93) Magnus, P. Sur le denomination botanique des espèces du genere Laestadia Awd. Bul. Soc. Myc. France, 9: 174. 1893.

('93) ——— ——— Einige Worte zu P. A. Saccardo's Kritik der von O. Kuntze in seiner Revisio etc. Hedw. 32: 64–66. 1893.

('94) ——— ——— Wie ist die Pilzgattung Laestadia jetzt zu bezeichnen? Oesterr. bot. Zeitschr. 44: 201–203. 1894.

('97) Lindau, G. in Engler und Prantl, Die Naturlichen Pflanzenfamilien, I Theil, 1 abth. l. c. 422.

is a synonym of *Stigmatea* Fr. and there treats it as such. Traverso ('02) regards the type of *Carlia* (*C. oxalidis*) as one of the Sphaeropsidaceae, perhaps a *Hendersonia*. Rabenhorst's original description would lead one to think as much.*

Bornorden ('64) l. c., p. 152, under Perisporiacei writes: "6. *Carlia* Rabenh., Herb. mycolog., pyrenis, globosis, minimis, ostiolo simplici apertis; sporis fusiformibus, ventricosis, ascis curtus, crassis.

"Diese Gattung wurde zuerst durch Rabenhorst in einer Species, *Carlia Oxalidis*, in dem Herb. mycologicum mitgetheilt, ist auch in der Fuckel'schen Sammlung enthalten—

"1. *Carlia Oxalidis* Rab., pyreniis nigris, minimis, globosis, epidermide tectis, prominulus; ascis sessilibus, curtis, lanceolatis et fasciculatim conjunctus; spores fusiformibus, ventricosis, hyalinis. Hab. in foliis vivis.

"2. *Carlia maculiformis*, Syn.: *Sphacria maculiformis* Fr. Syst. II, p. 524. pyreniis minimis, etc. Tab. I, Fig. 21.

"3. *Carlia Laburni* Bon., pyreniis globosis, etc.,—Tab. I, Fig. 23."

It will be noticed that this generic description does not correspond at all with that of Rabenhorst 1858. This seems to have constituted an emendation of the genus and Bonorden should be cited as the author.

But Dr. G. Winter ('86) states that upon examination of the Rabenhorstian specimen (in herb. mycol. edit. II, no. 567) he finds it to be *Sphaerella depazeaformis*. Thus the species cited as type falls into synonymy. Of the two remaining species listed by Bonorden, which by some might be taken as type, Winter ('87) retains the second in the Auerswaldian genus *Laestadia* and transfers the third to the genus *Physalospora*. Whether or not the name *Carlia* is valid as a name for a genus of *Mycosphaerellae* and whether it should in any way be connected with the name of the Black Rot fungus can be determined only by a very careful monograph of this very large and imperfectly understood group.

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* Flora 40: 382. 1857. *Carlia* Rabenh. Mspt. Sphaeriacearum nov. genus Hormosporae DeN. affine. Perithecia minuta subglobosa e macula prominula. Sporae sphaericae initio toruloidiconcatenatae, episporio crasso, brunneo. Asci nulli. 567 C. Oxalidis Rabenh. perith. atris in macula fusco-subsphacelata, sporis minutissimis fuscis toruloidibus."

('64) Bonorden, H. F. Abhandlungen aus dem Gebiete der Mykologie. Halle. 1864.

('86) Winter, G. Nachträge und Berichtigungen zu Saccardo's Sylloge Fungorum Vols. I, II. Hedwigia 25: 10–28. 1886.

('87) Winter, G. In Rabenhorst, Kryptogamen-Flora I, 2, 403 and 414. 1887.

('02) Traverso, J. B. Flora Italica Cryptogamia, 2: 375. 1902.

A list of the more important names applied to this fungus is as follows:

Guignardia bidwellii (Ellis) Viala et Ravaz.
Bul. Soc. Myc. France, 8: 63. 1892.

Sphaeria bidwellii Ellis.
Bul. Torr. Bot. Club 7: 90. 1880.

Physalospora bidwellii (Ellis) Sacc.
Sylloge Fungorum 1: 441. 1882.

Laestadia bidwellii (Ellis) Viala et Ravaz.
Prog. Agr. et Vit. 9: 490–493. 1888.

Carlia bidwellii (Ellis) Magnus.
Bul. Soc. Myc. France, 9: 174. 1893.

Guignardia ampelicida (Engelmann) Roze.
Bul. Soc. Myc. France, 14: 24–26. 1898.

Naemospora ampelicida Engelmann.
Trans. St. Louis Acad. Sci., Jour. Proc. 2: 165. 1881.

Phoma uvicola Berkeley & Curtis.
Grevillea 2: 82. 1873.

Phoma ustulatum Berkeley and Curtis.
Grevillea 2: 82. 1873.

Phoma uvicola var. *labruscae* von Thümen.
Die Pilze des Weinstockes. 1878. p. 16.

Depazea labruscae Engelmann.
Trans. St. Louis Acad. Sci., Jour. Proc. 3: ccxv. 1877.

Phyllosticta viticola von Thümen.
Die Pilze des Weinstockes. 1878. p. 188.

Phyllosticta labruscae von Thümen.
Die Pilze des Weinstockes. 1878. p. 189.

Phyllosticta ampelopsidis Ellis & Martin.
Ellis' North American Fungi. No. 1169.

Life history — Perithecia

The various manifestations of this polymorphic fungus make a study of its life history exceedingly interesting. The observations recorded here have been taken as they occur naturally under most favorable conditions, and observations have extended over two seasons, the entire time being devoted to this one particular factor.

Upon entering, early in the spring, a vineyard which has had Black Rot the year previous, one finds that most of the mummied clusters of

the previous year are lodged on the ground, having been broken loose from the vine and dropped there at the time of trimming and pulling the brush. (Fig. 138.) Careful examination of such mummies with the unaided eye shows the presence of very numerous minute elevations which are the fruiting conceptacles or perithecia of the fungus. A slight perforation or rupture at the apex, scarcely visible to the naked eye, is the ostiole. At first, the writer had expected to find the best perithecia for study on or near the side of the berry in contact with or imbedded in the soil. After frequent examinations, he found that

FIG. 138.— *Mummied cluster of grapes clinging to the wire and forming a center of infection. (Natural size.) Photo. July* 1, 1908.

the perithecia in such locations were usually barren and that it was on the upper, exposed side, where outwardly the mummy appeared to be very dry, that these developed best. From this observation, he was led to examine more closely mummies which cling to the wires. While perithecia on them were not mature so early in the season, there was a greater abundance of them in a living condition than when on the ground. On making a thin section through a region bearing perithecia, all sorts of conditions are to be found (Fig. 139 and Plate II, Fig. 7) —

ascigerous perithecia in all stages of development, pycnidia and spermogonia containing pycnospores, and spermatia from the previous season.

On April 23, 1908, clusters of Black Rot mummies were collected at Lake Ridge, N. Y. Examination showed that at this time no development had taken place. These mummies were placed in a stender dish, and although overrun with *Cephalothecium roseum,* continued to develop, and on May 16 the writer found asci with spores that were apparently mature. On this latter date a cluster of mummies was picked from the wires at Ithaca and examination showed that the perithecia

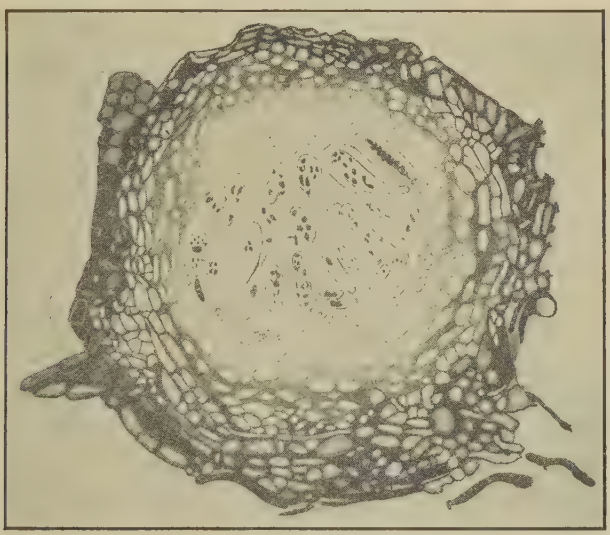

FIG. 139.— *Cross section through a perithecium showing developing asci and ascospores. Outlined with a camera lucida.*

were just beginning to develop. Some of the internal cells were slightly elongated. Under natural conditions development had been retarded.

On March 27, 1907, mummied clusters were sent to Ithaca by Mr. G. G. Lansing, Romulus, N. Y. These were kept in a stender dish with moist cotton about them. On April 25 an examination was made just prior to discarding the whole lot, when mature asci with spores were found. On June 13, 1907, the writer's first examination was made for asci developed under field conditions, and an abundance of them were found at that time. The spring had been exceptionally cold and wet,

but as has been pointed out by Prunet ('97), perithecia will develop at a very low temperature if sufficient moisture is present.

At frequent intervals throughout the summer examinations were made to see just how long the asci persisted. From the observations of Scribner and Viala ('88), which have been copied widely, the writer had expected them to disappear early in the season. When he found asci with spores that were immature in August, 1907, he thought it was probably due to the very dry summer which we had experienced. When, however, he found on October 2, 1907, an abundance of asci with spores which germinated readily in tap water after sixty hours, he was convinced that the ascigerous stage was not so evanescent as he had been led to believe. Data obtained in 1908 confirmed this observation.

On July 21, 1907, mummies containing quantities of asci, both immature and mature, were enclosed in a piece of wire cloth and buried in the ground to a depth of about six inches. On October 24, these were taken up and examined. No evidence of spores of any kind was found, and in fact many of the mummies were completely disintegrated.

An even more conclusive experiment on this subject was terminated July 16, 1907. In a particular section of a Niagara vineyard where no fruit had been picked in 1906 because of the great abundance of Black Rot, the whole rotted mass went onto the ground and was plowed under early in May. As many vineyardists "plow back," the writer decided to see whether this would be advisable in such a rot-infested section. Consequently, a few rows were plowed back in the usual way. The writer then made a search for mummies but much to his surprise was not able to find any. An occasional remnant was found. Believing that the plow had not gone deeply enough, a spade was brought into use. With this, even after continued search, only an occasional mummy was found. A microscopic examination of such mummies showed them to be in an advanced stage of disintegration and entirely void of spores. This, too, had taken place in a season which had been relatively dry. It therefore seems quite certain that, although spores may be formed in perithecia during most of the summer, under normal conditions they are destroyed in a few weeks (six or eight) if buried under a few inches of soil. Galloway ('89) has shown that the same thing holds true if the mummies are covered in the autumn. This is of considerable

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('88) Scribner, F. L. and Viala, P. Black Rot. U. S. D. A., Sec. Veg. Path. Bul. 7: l. c. 22. 1888.

('89) Galloway, B. T. Ascospores of the Black Rot Fungus as affected by covering with earth. Jour. Myc. 5: 92–93. 1889.

('97) Prunet, A. Les formes du parasite du Black-Rot, de l'automne au printemps (1). Prog. Agr. et Vit. 27: l. c. 295. 1897.

interest and importance from the practical standpoint, for if rotted clusters are removed from the arms and dropped on the ground at trimming time and then covered with the plow, these sources of infection will be eliminated.

Origin and development of the ascus (Plate I, Figs. 1–6.)

The writer had hoped to make a critical study of this point as there are many interesting biological considerations connected with it. However, he soon found that such a study was, alone, sufficient material for a major problem, and that part of it would have to be left until another time. One of the chief difficulties met with is the extreme minuteness of the nuclei.

Upon examination of well-stained microtome sections of perithecia taken June 16 to 22, 1907, and in various stages of development, it is easy to find ones in which there is practically no development from the winter condition. Such perithecia are surrounded by the usual thick, black, pseudoparenchymatous covering. This pseudoparenchyma becomes thinner walled inwardly, so that the whole interior of the perithecium is filled with it. In the stained sections there are scattered here and there, near or a little below the centre of the perithecium, little dots of much deeper staining quality, which in well-bleached preparations are seen to be individual cells when examined with an immersion lens. From a series of successive stages which are readily obtainable, it seems clear that these cells which stain more intensely are ascogenous cells, the remaining cells serving purely as nurse cells. Each individual cell has a nucleus, but nuclei in these deeply staining cells retain the stain much more tenaciously than the others. When activity begins, the ascogenous cell elongates by pushing its way upward, though at the very first it seems to take the path of least resistance and may grow in a longitudinal direction for some distance. (Plate I, Figs. 1 and 2.) When the ascogenous cell is half the length of a mature ascus, one can sometimes see a single large nucleus in the centre of the cell or somewhat distad of the centre. (Plate I, Fig. 3.) The apex of the cell, which up to this time has been somewhat acute, now becomes obtuse as the cell enlarges at the tip and becomes clavate. The writer has noticed that at this stage the protoplasm in the base of the ascogenous cell seems to recede a little distance and sometimes apparently lays down a wall, leaving a small empty cell at the foot of the ascus.

Whatever takes place now, does so very rapidly. The writer has been unable to get transition stages between the uninucleate condition and one in which all of the spores are more or less clearly outlined and

each possessing one to four nuclei, usually two or three. (Plate I, Figs. 4 and 5.)

There are a number of these ascogenous cells in a perithecium generally fifty to one hundred or even more. As has been pointed out above, they do not mature synchronously, and when several asci are found in a perithecium it is very evident that much of the pseudoparenchyma has gone. The writer is of the opinion that these cells are absorbed by the developing asci. Now, early in the season when the very first asci are developing, not nearly all of the pseudoparenchymatous mass has disappeared, and when crowded together by the development and expansion of two asci situated rather close together, often, in poorly stained preparations, gives the impression of paraphyses between the asci. The writer is satisfied, however, that there are no true paraphyses developed here as there are in the case of so many discomycetous fungi, as well as other *Pyrenomycetes*.

In this connection Scribner ('86) inserts the following foot note: "Mr. Smith (Erwin F.) in his investigations above referred to, found the ascosporous form very frequent in the berries examined after May 10. He discovered asci in all stages of development from very small immature ones to perfect ones containing well developed ascospores. *Mingled with the asci were the usual paraphyses.*" Price ('92) figures some bodies which he records doubtfully as paraphyses. The writer has often seen about the mouth of the perithecium short chains of moniliform cells tapering toward the ostiole which look very much like the ones figured by Price, but these are attached to the periphery of the perithecium and near the upper part. The writer has usually designated them as periphyses. He has never seen such cells intermingled with the asci nor any cells which he could interpret as paraphyses. (Fig. 139.)

The spring rains furnish moisture conditions which favor the development of asci. When an ascus is mature, and this, depending on the season, may be at any time after the middle of May, it is a long clavate body with a very hyaline but thick wall which is a little thicker at the apex than at any other place. (Plate V, Fig. 26.) It contains eight spores placed in a single series and usually all having a similar orientation. The size of the ascus varies with the method of observation. If the section is made dry, the ascus measures 62 to 80 by 9 to 12 microns;

('86) Scribner, F. L. Report on the Fungous Diseases of the Grape Vine. U. S. D. A., Bot. Div., Sec. Plant Path. Bul. 2: l. c. 33. 1886.

('92) Price, R. H. Black Rot of the Grape. Texas Agr. Exp. Sta. Bul. 23: 217–231. 1892.

but if, in an aqueous mount, it may vary up to twice that length. The writer did not at once sufficiently appreciate this remarkable adaptation. His first sections of Black Rot perithecia were mounted in water and he often noticed that in some cases asci protruded for some distance through the ostiole. Before very long he saw one of these increasing in length and also found that it was by the absorption of water that it elongated. When mounted dry the asci were contained within the perithecium, but when a drop of water was drawn under the cover glass the process of elongation could be observed. The wall of the ascus undergoes a gelatinization, broadens out to several times its original thickness, and becomes perfectly hyaline. The only way its presence may be detected is by a very faint line caused by diffraction at its inner edge and by the fact that the spores lie in perfect order. When the ascus has protruded to nearly its original length outside the perithecium, the spores will usually be found crowded to the distal end. One can almost see an uneasiness among the spores, especially the distal one, and soon an undoubted movement can be seen. The tip of the spore is closely applied to the apex of the ascus and one can see that it is slowly forcing its way to the exterior. There is no evidence of a pore at the apex of the ascus either in fresh or stained material. Soon the spore, which is widest at the middle, seems to have passed a critical point and is suddenly and violently ejected. The passage is so rapid that it can not be followed under the microscope and unless one uses a low power (16 mm. objective) the spore is cast entirely out of the field even though it must pass through a liquid medium and is confined under a cover glass. The writer has found spores lodged 100 to 200 microns from the apex of the ascus. In one case (notes of June 13, 1907) a second spore followed the first immediately and a third in five seconds more; in another observation (July 4, 1907) the writer saw an ascus entirely empty itself in the course of ten minutes. A similar process has been observed in *Gnomonia erythrostoma,* a somewhat closely related fungus, by Frank ('86), and Frank states that Zopf has observed such a discharge of ascospores in *Chaetomium*. The discharge of ascospores has been observed in *Guignardia* by Prillieux

('86) Frank, B. Uber Gnomonia erythrostoma die Ursache einer jetzt herrschenden Blattkrankheit der Süsskirchen im Altenlande, nebst bemerkungen über Infection bie Blattbewohnenden Ascomyceten der Bäume überhaupt. Ber. d. deutsch. bot. Gesell. 4: l. c. 201–203. 1886.

('88), Scribner and Viala ('88), and others. The latter state that the ascus is discharged from the perithecium, after which the spores are expelled. The writer has never seen such an occurrence. But Scribner ('88) the same year describes the process much as given above.

Scribner and Viala (l. c.) describe a very convenient method for determining the distance to which spores may be discharged. By floating a piece of cork, just large enough to bear up a mummied berry in a test tube containing water, the level may easily be raised and lowered and discharged spores caught on a cover glass. According to their observations, and the writer's confirm them, "the height of projection does not exceed 4 cm.; at 2 cm. or less, the greatest number of ascospores can be obtained."

Except for the work of Frank just cited, the writer has never seen this method of dehiscence of the perithecium and projection of ascospores given the consideration that its significance would seem to warrant. The adaptation is perfect. With each succeeding rain during the summer, mummies are moistened, the mature asci absorb water, swell, protrude beyond the perithecial wall, and discharge ascospores into the air. This is a most effectual means of dissemination, and at an opportune time, too, since the moisture, as will be seen later, affords opportunity for the germination of spores. It now becomes apparent, also, how futile are the efforts of certain experimenters to control Black Rot by spraying the mummied clusters. The amount of moisture reaching the mummies would not be sufficient to effect a discharge of ascospores and in any case the spray substance would not reach the spore.

The spore as it is shot from the ascus and floats about in the water is ovoid, but is often swollen slightly eccentrically. (Plate V, Fig. 27.) The swelling of the spore is often quite conspicuous because of the abrupt constriction on either side, as seen in optical section. The spores are hyaline, with very finely granular contents and with two large refractive dots near the swollen part. To all appearances the ascospore is one celled. Upon careful observation one can see on one end an inflated hyaline vesicle which the writer formerly regarded as a second cell, and thus showing a close relationship of the fungus to other Mycosphaerellaceae. The appearance of the cell is not at all like the small cell of a *Gnomonia* spore, however, and in microtome sections the writer is not able to distinguish this pseudo-cell at all, so that he agrees

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('88) Prillieux, Ed. Production de périthèces de Physalospora bidwellii au printemps sur les grains de raisins attaqués l'année précédente par le Black Rot. Bul. Soc. Myc. France. 4: 59–61. 1888.

('88) Scribner, F. L. and Viala, P. Black Rot. U. S. D. A., Bot. Div., Sec. Veg. Path. Bul. 7: l. c. 23. 1888.

('88) Scribner, F. L. New Observations on the Fungus of Black Rot of Grapes. Proc. Soc. Prom. Agr. Sci. 9: 68–72. 1888.

with Prillieux ('88) "that they bear at their extremity a little mucilaginous material, inflated and transparent, which probably aids in fixing them to the leaf where they may germinate." When left in water a few hours the vesicle becomes so transparent as not to be seen at all.

The spores germinate slowly even under the most favorable conditions. On a glass slide in distilled water, in fresh rain water, sugar solutions, etc., or on a berry or leaf in a drop of any of these liquids, either on the vine or in a moist chamber, and at various natural temperatures, the writer has never succeeded in obtaining germ-tubes on ascospores in less than thirty-six hours. It is more often forty or even sixty hours. Drawings in Fig. 28, Plate V, show forty-eight hour germ-tubes. These are the longest tubes obtained at forty-eight hours, but some of them are long enough to have reached beneath the cuticle and epidermis and have established themselves. The germ-tube may come from any point on the spore but usually from the side. The spore does not become septate on germination.

Meteorological relations

An examination of the appended meteorological data (p. 347) will show that at intervals during the summer months there have been periods of rain or rain followed by fogs or cloudy weather of two to three days duration or even more. This is longer than is required for the germination of ascospores. The rain furnished water for the discharge of the ascospores and also the moisture necessary for their germination. The writer will refer to this matter again under the heading "control," since here seems to lie the fundamental basis for a rational method of control.

Logically, the writer should first discuss the entrance of the germ-tube, but this has been left until a later heading. He will discuss there his many futile attempts to observe this.

Mycelium

It seems certain, however, that the germ-tube of these spores must penetrate the cuticle and in some way get to the interior. There the mycelium develops slowly by the further growth and branching of the germ-tube. It ramifies the parts attacked to a distance nearly equalling the limits of the lesion. That it does not extend fully as far as the lesion would seem to indicate that some substance is excreted which precedes the mycelium for some distance, killing the host cells in advance. The mycelium during this period of incubation does not develop rapidly, seeming to indicate that it has some difficulty in overcoming the

('88) Prillieux, Ed. Bul. Soc. Myc. France 4: 59–61. 1888.

resistance of the cells of the host. Plate II, Fig. 8 is a photomicrograph of a sector of a thin slice from the surface of a berry and includes only a lesion which is not more than twelve hours old. The germ-tube of the spore entered at least ten days previous. The radiating mycelium, stained with eosin, can be seen and an examination shows it to be of limited extent. Also, cross sections of such spots show that it has penetrated only to a short distance. At this stage the mycelium is hyaline, with granular contents, frequently septate, very irregular in diameter even in the same hypha, producing gnarled lateral branches and proceeding by gnarled blunt tips as well as by acute ones. It measures in diameter from 1.5 to 3.5 microns. Examination shows it to be not only intercellular but also intracellular. Haustoria are not developed. Old mycelium becomes brownish in color. That part which becomes modified to form fruiting bodies turns yellow, then brown, and later becomes very black. (Plate IV, Fig. 25.)

Period of incubation

After a period of time, spoken of as the period of incubation, the effect of the mycelium is apparent to the eye, in the form of lesions already described. This period of incubation varies with the weather conditions. With hot and dry weather the period is materially reduced, and with moist cool weather it is longer. In tender, juicy fruits, also, the period is shorter than in stems and leaves. The writer has observed spots on fruits eight days after the rain which permitted the infection and on leaves two days later, while in other cases he has recorded incubation periods of eighteen days on fruits and twenty-one days on leaves. Prunet ('98) states that the period of incubation may be ten to twelve days in July and twenty-two to twenty-five days in April and May. Infections from the three rainy days of June 22nd, 23rd, and 24th, 1908, appeared on the afternoon of the three successive days July 3rd, 4th, and 5th, thus making the period of incubation just ten days in length. On July 10, 1907, a very general infection appeared, following a continued rain which began in the evening of June 22, the period of incubation in this case being eighteen days for fruits and twenty to twenty-one days on leaves. Many other instances might be cited.

Period of susceptibility

It is also of interest to see what aged leaves and fruits are infected. After seeing the resulting spots from the infection of June 22, 1907,

('98) Prunet, A. Observations et expériences sur le Black Rot. Rev. Vit. 9: l. c. 658. 1898.

which appeared July 12, it soon became apparent that only certain aged leaves had been infected. The first leaf of a shoot practically never had spots on it, the second often had several, but the third invariably had spots on it if there were spots on any of the leaves. The fourth leaf was nearly always free and the fifth or sixth was usually terminal and also free. Fortunately the writer has a photograph of a vine, made June 22, 1907. (Figs. 140 and 141.) This shows that on the date on

FIG. 140.— *Shows stage of development of vines at Romulus, N. Y., on June 22, 1907, the date of the first infection of the season.*

which infection actually took place, the third leaf on most of the shoots was really not fully expanded, so that it was still in a tender and growing stage. The fourth leaf was still smaller at that time, if it had unfolded at all. In some cases shoots had not made as much progress as in others, and on them the second leaf was still growing and in fact in some just expanding. Observations in confirmation of this fact have been made in connection with many infections, and it is very evident that only leaves which are in a tender and growing condition are sus-

ceptible of infection. It is unusual to find Black Rot spots of different ages on the same leaf. In 1907, the writer did not find such a condition, but on June 13, 1908, he found very small young spots on leaves which had developed spots first on June 10th. This may be explained by the fact that two rains came so close together that a very small leaf had not matured sufficiently to become immune to infection. A similar condition was found on July 6, 1908, from the separate infections of June 22nd, 23rd, and 24th.

FIG. 141.—A *photograph at closer range of a few shoots shown in Fig.* 140.

The writer soon noticed that to locate Rot lesions on shoots it was necessary only to find a spotted leaf. In the vicinity of spotted leaves, and only there, can one readily find lesions on green shoots, leaf petioles or tendrils. These parts, of course, are also in a growing condition at the time of infection of the leaf, and as soon as the tissue becomes firm and hard, infection does not occur.

The early infections which appear on the leaves do not develop on the clusters except on the pedicle. The calyx cap seems to be a protection to the young berry. The pedicles are often infected, however, and thus prevent the further development of the berry. As soon as the calyx has fallen, the berry is especially susceptible to infection and continues so throughout its existence.

The susceptibility of only certain aged leaves to infection seems to have been noted first by Viala ('89), but many others have recorded similar observations since and the facts have been worked out in detail by Prunet ('97) ('98) and figured. In Figs. 103 and 104 he shows the difference in thickness of the cuticle of a young leaf and an old one, and explains the phenomenon as one of purely mechanical difficulty. He also states that the cuticle of the berry never becomes suberized and thus explains the continued susceptibility of the berry to infection.

There is a popular belief among vineyardists that after a berry has reached a certain stage in its development, e. g. when the seed becomes hard, it becomes more or less resistant to attack. The reason for believing this is that late in the season (i. e. after July 20 to August 1) there are rarely new invasions which take down a marked amount of the crop. The writer has noticed this fact also, and for a time was at a loss for an explanation. However, he has never had any difficulty in finding occasional new rot spots on most varieties of grapes up to shipping time provided there had been a rain to allow for an infection and sufficient time had elapsed for incubation. The explanation, which he believes to be the correct one for this phenomenon, will be given later in this paper. (page 329.)

Origin and development of pycnidia

After the appearance of the Black Rot lesions it is remarkable with what great rapidity the pycnidia develop and form pycnospores. That the process is very rapid the writer found from his studies of their development. He has numerous sections of leaf spots which were preserved to show stages in the development of the pycnidium, but he finds very few transition stages. Either there is no evidence of pycnidia or they are fully developed and contain pycnospores. This shows that the process is very rapid and also seems to indicate that the greatest activity is at night, since he has never made a special effort to obtain material at night, but has fixed it at almost all hours during the day. He does find an occasional transitional stage, however.

The mycelium of the fungus is pretty well masked in the fresh leaf by the abundance of plastids of various sorts in the host cells, and in stained sections by the intense staining reaction of the contents of

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('89) Viala, P. Une Mission Viticole en Amérique. l. c. 239.

('97) Prunet, A. Sur l'évolution du Black Rot. Compt. Rend. Acad. Sci. Paris. 125: 664–667. 1897. Also, Prog. Agr. et Vit. 28: 598–600. 1897. 2e semestre.

('98) Prunet, A. Observations et éxperiences sur le Black Rot. Rev. Vit. 9: 497–505; 535–541; 601–603; 621–628; 656–664; 677–684. 1898.

these same cells. In prepared sections, stained with iron haematoxylin, the mycelium can be seen, however, as short, deeply staining bands or threads. At some point directly beneath the epidermis and between two of the underlying palisade cells, hyphae intertwine and form a gnarl. (Plate III, Fig 12.) By a rapid increase in the number of fungous cells as well as by a slight increase in the size of the individual cells, the adjacent host cells are pushed aside. Two palisade cells may be separated their entire length by the hyphal gnarl and the gnarl may even extend some distance into the spongy parenchyma. Mycelial filaments on the periphery of the gnarl anastomose to form a pseudoparenchyma. The point of greatest activity seems to be on the interior of the gnarl, and with continued growth there the still flexible wall of the pycnidium is forced centrifugally in all directions. At this time the epidermis of the leaf is thereby slightly elevated and the cuticle broken, thus giving the first external evidence of the developing pycnidium. Since the processes are identical, we will now bring the development of the pycnidium in berries up to this point and then carry the description of both through the formation and discharge of spores.

The writer has intimated above that the process of the formation of pycnidia is a rapid one. Their development in the fruit has been studied with great care and considerable accuracy with respect to the time element. This was in connection with a study of the successive histological changes which take place in the structure of the berry as the disease progresses. On July 3rd, 4th, and 5th, 1908, new infections appeared in great abundance on the fruit, following the rains of June 22nd, 23rd, and 24th. Between 11:30 a. m. and 1 p. m. on each of these days, an enormous number of new lesions appeared and, being separated by twenty-four and forty-eight hours respectively, were readily distinguishable for several days. Examination of lesions approximately thirty hours old (taken July 4th at 6 p. m.), either in stained sections or in fresh condition, does not reveal the faintest trace of pycnidial formation. But material taken at 5:30 a. m., July 5th (forty-two hours), shows that pycnidia have not only formed during the night, but that spores are already present in quantity. Since the writer had not anticipated such rapid development, it was fortunate that from the infection which appeared July 4th, he examined and preserved material for sections in which the lesions were approximately thirty-six hours old, and which may be substituted for July 4th, 12 p. m., in this series.

In this material he finds an abundance of pycnidia in all stages of development. The pycnidium is developed by the interweaving and later the anastomosing of mycelial hyphae at a point just under the epidermis

and between the cells of, or, in rare cases, deep in, the hypodermal parenchyma. The rapidity of formation is astonishing. In six hours, more or less, after stages shown in Plate III, Fig. 12, we have a condition seen in Plate III, Fig. 13. Cells of the hypodermal parenchyma are pushed back until quite a cavity is formed. As previously mentioned, this is by a rapid growth in the interior of the gnarled mass of hyphae causing an outward pressure. Soon the innermost hyphae of the young pycnidium are seen (in cross-section) to be much less interwoven and not anastomosed at all. (Plate II, Fig. 11.) They also extend radially toward the centre. Now the tips of these cells which grow downward toward the centre of the now more or less evident pycnidium, as they reach the centre, become enlarged and clavate. Soon a constriction just back of the clavate head becomes evident. This becomes deeper and deeper and soon the tip is entirely abstricted, thus forming a pycnospore. (Plate II, Fig 10.) The young pycnospores may be variously shaped. Some are elongate, others are curved, while still others are nearly globose. There is more or less a tendency for them to become ovoid when the pressure from all sides becomes equal, but as can be seen from the illustrations and measurements they are not always so. (Plate V, Figs. 30, 31 32.)

Quantities of these spores are formed, and the cavity which contains them becomes larger either at the expense of the pseudoparenchyma lining the pycnidium or by the crowding back of the heavier walls. It seems that both factors enter, and since the thick walled pseudoparenchymatous cells are elongated and not globose would seem to indicate that the latter factor is of some importance.

In the case of lesions on leaves or stems the pycnidia develop almost simultaneously, but on the berry pycnidia appear first at the centre of the lesion (first visible to the naked eye as a blackening) and follow in regular sequence the progress of the lesion until in a week or ten days the whole berry is blackened. The writer had expected to find in berries which were only partially blackened that sections made in the right direction would show pycnidia in all stages of development. However, on careful examination he found that this is not true, and he is at a loss for an explanation unless it be that the formation of new pycnidia takes place exclusively at night and that the process is so rapid that by the next morning the spores are developed. Material taken 12 p. m., July 5, 1908, shows an abundance of young stages. The mature pycnidium varies considerably in size and shape, but all variations can be found on all parts of the vine attacked. Pycnidia are usually globose or nearly so and may be from 80 to 180 microns in

diameter. Sometimes the pycnidium is somewhat flattened and has a short stoma. On leaves there is a well-delevoped ostiole (Plate II, Fig. 9), but pycnidia on fruits do not always have this so well developed.

As the pycnospores are developed, they are enveloped in a mass of gelatinous matter so that they are held apart. The gelatinous matter does not stain and in photomicrographs of a section the spores seem to be isolated. With moisture this gelatinous matter swells, and in this way each rain that comes after the pycnospores are developed causes their discharge from the pycnidium. Prunet ('99) has shown that pycnospores will not be discharged unless there is moisture present. He found pycnidia two months old in which the pycnospores were intact owing to the lack of precipitation. Following a rain or even very heavy fog or dew it is easy to find these pycnospores exuded from the pycnidium, occasionally in a short white "worm" a few millimeters in length, but more frequently forming a whitish cap on the apex of the pycnidium.

Pycnospores (Plate V, Figs. 30–36.)

The mature pycnospore as it is extruded from the pycnidium is globose, ovoid, or sometimes oblong. It measures 8.5 to 11.5 by 6.5 to 8.5 microns. Its contents are coarsely granular, i. e. it is packed very full of large globules of substance which appear oily. In stained sections it is seen to be bi-nucleate. (Plate III, Fig. 18.) It is hyaline and does not become darker nor septate on germination. Shear ('07) reports the presence of a very hyaline appendange at the apex of the pycnospore. He figures such an appendage on pycnospores of Guignardia vaccinii. In his description he states that "it (appendage) is, however, shorter and less easily distinguished than that of Guignardia vaccinii, and soon disappears in mounted specimens." With this statement in mind, the writer has made very careful examinations, with an immersion objective, of pycnospores from leaves, stems, and fruits, when young as well as when extruded from the pycnidium, and has never yet been able to see this appendage. The only case approaching this condition, which he has seen, was one in which the spore had not yet been entirely abstricted from the basal cell, the latter clinging to it as an appendage. Dr. Shear has assured the present writer that he has often seen this appendage, and the latter is at a loss to explain why he has not succeeded in seeing it, unless, indeed, it is not constantly formed.

('99) Prunet, A. Nouvelles recherches sur le Black Rot. Rev. Vit. 12: l. c. 112. 1899.

('07) Shear, C. L. Cranberry Diseases. U. S. D. A., B. P. I. Bul. 110: l. c. 15. 1907.

Germination of pycnospores

The pycnospores germinate readily in distilled or rain water, producing a single simple germ-tube as shown in Fig. 34, Plate V. The length of time for germination varies considerably and for no known reason. The writer finds in his notes of July 11, 1908, the statement that "conidia put to germinate yesterday have germinated at the end of twenty hours with a long germ-tube." This was on fruit. And further, "germination seems about as good in distilled or rain water on slides as in the same liquids on the surface of berries or leaves." Often he has not observed germination in less than twenty-four or even thirty-six hours. But with the above data at hand, it was evident that the germ-tube was much longer than would be necessary to pierce the cuticle and place the developing mycelium beyond the harm of a toxic spray. On July 14, 1908, "pycnospores were placed in drops of water on berries at 9 a. m. Six hours later, examinations were made to see how far germination has progressed. A very few spores had germinated slightly; most had not gone far enough to show a germ-tube."* Again on July 17, 1908, similar studies were made. At the end of twelve hours, examination "shows that some of the pycnospores have already germinated though the number is relatively small." (Plate V, Fig. 33.) These studies were made under practically natural conditions in relation to temperature and moisture and were in drops of water on the surface of berries the clusters of which had been freshly picked and placed in a moist chamber.

Viala et Ravaz ('88) state that pycnospores will germinate in three or four hours, while Scribner ('86) states that "the stylospores germinate freely in water within the space of three or four hours." But more recently Ravaz et Gouirand ('97), after an extended germination study, state that pycnospores rarely germinate in rain water in less than twelve hours and it is more often twenty-four hours. These authors also state that spores do not germinate in a humid atmosphere but must have precipitated moisture. It seems evident, then, that frequently in ten to twelve hours in our region a pycnospore may have germinated, and, if the germ-tube penetrates the berry directly, have become established under the cuticle or epidermis of the host and independent of external conditions.

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* Quotations from the writer's field notes.

('86) Scribner, F. L. Botanical Characters of the Black Rot, Physalospora bidwellii Sacc. Bot. Gaz. 11: 297–302. 1886.

('88) Viala, P. et Ravaz, L. Le Black Rot et le Coniothyrium diplodiella. Montpellier. 1888, deuxième édition. l. c. 24.

('97) Ravaz, L. et Gouirand, G. Recherches sur le traitement des maladies de la Vigne. Rev. Vit. 7: l. c. 307. 1897. 1er semestre.

Appressoria

It is known that upon germination many spores produce a short tube on the end of which a spore-like body, commonly known as an appressorium, is developed. Frank ('86) records a similarly developed body on the germinating spores of *Gnomonia erythrostoma,* a fungus somewhat closely related to the Black Rot fungus. He finds that the tube of penetration develops from this appressorium. Appressoria in the anthracnose fungi are well known from the studies of Halsted ('93) and of Hasselbring ('06), who gives a resume of the literature on the subject. Prunet ('98) has seen and illustrates the secondary spores on the germ-tubes of germinating ascospores of Guignardia bidwellii. He regards them as especially resistant. Some are figured as having two or three cells.

In the present writer's numerous attempts to observe the entrance of the germ-tube, he has seen many germinated ascospores and pycnospores. In July, 1908, he noticed in some germinated pycnospores that at the end of the germ-tube there was an appressorium-like body. This body is brown and cut off by a septum. Its contents are densely granular and highly refringent. The old spore and tube are practically void of contents except for a thin film of protoplasm which lines the spore wall. Upon examining some preserved slides of ascospores, he found there also that many germ-tubes had an appressorium at the end, though in case of both kinds of spores many are without appressoria. (Plate V, Figs. 29 and 36.) These bodies may function as in Gnomonia and it is possible that, had the writer given more attention to them, he might have found an entering germ-tube. On the other hand, they may serve as a secondary conidium in case the germ-tube of the spore fails to penetrate at the first attempt. The writer has seen cases in which the appressorium had produced a secondary mycelial tube or germ-tube.

('86) Frank, B. Ueber Gnomonia erythrostoma die Ursache einer jetzt herrschenden Blattkrankheit der süsskirchen im Altenlande, nebst bemerkungen über Infection bei Blattbewohnenden Ascomyceten der Bäume überhaupt. Ber. d. deutsch. bot. Gesell. 4: l. c. 201–203. 1886.

('93) Halsted, B. D. The Secondary Spores in Anthracnoses. N. J. Agr. Exp. Sta. Rept. Bot. Dept. for 1892: 303–306. 1893.

('98) Prunet, A. Observations et expériences sur le Black Rot. Rev. Vit. 9: l. c. 623. 1898. Fig. III.

('06) Hasselbring, H. The Appressoria of the Anthracnoses. Bot. Gaz. 42: 135–142. 1906.

Longevity of pycnospores

Pycnospores are often short lived spores, but it is not so in the case of the Black Rot fungus. Scribner ('88) says, "I have germinated them in water after having kept them in a dry place for six months." Ravaz et Gouirand ('97) germinated spores in January which had developed on spots May 15 and 16 of the previous summer. It is a generally recorded fact that the pycnospores may live over winter. The writer has found this to be of very frequent occurrence. Examination of old mummies for perithecia will almost always show the presence of some

FIG. 142.—*Black Rot lesions on one year old canes.* (*Natural size.*) *Photo. Aug. 22, 1907.*

pycnospores. On June 25, 1907, he found quantities of such spores germinating after twenty hours, both in rain water and in sugar solution. The tubes were long (Plate V, Fig. 34) and capable of having produced an infection had they penetrated directly. Fig. 142 shows pycnidia on canes, while Figs. 14, 15 and 16 in Plate III, show a section of a wintered petiole collected June 24, 1908, with pycnidia and pycnospores. Even the basal cells seem to be active and it is a question

('88) Scribner, F. L. New Observations on the Fungus of Black Rot of Grapes. Proc. Soc. Prom. Agr. Sci. 9: l. c. 71. 1888.

('97) Ravaz et Gouirand. Rev. Vit. 7: l. c. 306. 1897.

whether these spores have not been developed since the warm rains of the season of 1908. The writer has usually regarded them as spores which have lived over winter, but of this he is not absolutely sure.

Infection from pycnospores on wintered parts

In the spring of 1907, such quantities of ascospores were developed and it was so easy to trace infections to such a source that sufficient attention was not given to other means of the fungus passing the winter. However, the writer has recorded the germination of pycnospores from mummied berries. About August 1, 1907, he found the lesions shown in Fig. 142, and after that had no difficulty in finding lesions both on old canes and tendrils. Because of the very small amount of rot in 1907, a relatively small number of perithecia were formed in the spring of 1908. So many cases of extreme infection were found that, knowing of the occurrence of pycnospores on dead parts, it was not difficult in many cases to locate the sources of infection. Careful examination would usually show the presence of pycnospores on old canes, tendrils or leaf petioles. The writer feels safe in saying that more than half of the primary infections of 1908 in the vineyard at Romulus were from pycnospores rather than from ascospores. He had thought from examinations that pycnospores were the only bodies of reproduction ever developed on canes, tendrils, etc., but in studying a microtome section of a leaf petiole shown in Plate III, Fig. 14, he found a perithecium containing some immature ascospores. (Plate I, Fig. 6.) This was not entirely unexpected, for in 1907 he had found pedicles with quantities of perithecia on them. However, he believes the occurrence of perithecia on such parts is relatively rare.

Spermogonia (Plate III, Fig. 19, and Plate IV, Figs. 21, 22 and 25.)

When Engelmann studied the Black Rot fungus in 1861 it was the spermogonial stage which he saw and described. Since that time, spermogonia have been seen and studied by nearly every worker who has dealt with this disease, and yet we seem no nearer a true explanation of their function than ever. They have been taken for reproductive bodies of a parasite on the Black Rot fungus. (See the following reference, l. c. 31, 32.) Viala et Ravaz ('88) claim to have proved conclusively that they are simply a stage of the Black Rot fungus, and they are of the opinion that the spermatia are "designed to disseminate the fungus during its period of activity on account of their extreme light-

('88) Viala, P. et Ravaz L. Le Black Rot et le Coniothyrium diplodiella. Montpellier. 1888, deuxième édition. l. c. 34.

ness and probable resistance to dryness." It is very frequently stated that the spermogonia are formed early in the season and are not of general occurrence later. Scribner ('88) and Scribner and Viala ('88) are of this opinion. On the contrary, the present writer very rarely finds it to be the case. On berries which showed new lesions July 3rd, 4th and 5th, 1908, and on which numerous pycnidia were developed in a few days, he made frequent examinations for spermogonia. On July 10th, he wrote in his notes, " in all examinations thus far made there have been no indications of spermogonia in any case. They do not seem to be formed this early in the season." But such berries kept in a moist chamber for a few days developed spermogonia. On July 14th he wrote, " on examining sections of rotted berries numerous spermogonia with spermatia were found." Microtome sections of such material show that the number of spermogonia is in reality relatively small. On berries rotted by a later infection than the ones just mentioned, spermogonia are numerous, as can be seen in microtome sections made from material put up at that time. In material of October 5, 1907, spermogonia are very abundant. On this date, in walking through the vineyard many of the more recently rotted berries appeared shining as though oil had been poured over them. This was from the great quantity of exuded spermatia.

Development of spermogonia

The development of the spermogonium does not differ materially from that of the pycnidium, at least in early stages. Often it is developed in a stroma with the pycnidium, and the two are separated only by a thin membranous wall. The hyphal gnarl is present just below the epidermis. This develops as in the pycnidium, the hyphae becoming darker and darker and eventually anastomosing at the periphery. The development of the spermogonium is, however, not nearly so rapid as that of the pycnidium, so that one can find spermogonia in the younger stages of development more readily. The pseudoparenchyma at the periphery formed by the anastomosing of hyphae becomes darker as new pseudoparenchymatous, thinner walled, and lighter colored cells are formed on the interior. The young spermogonium is nearly filled with pseudoparenchyma and it is only in the very centre that a few hyphæ remain that do not anastomose. These hyphæ become arranged more or less radially, thus forming the basal cells for the abstriction of spermatia. The writer believes these cells are nourished to some extent by the pseudoparenchyma, for in old spermogonia the quantity of such cells

('88) Scribner, F. L. Proc. Soc. Prom. Agr. Sci. 9: l. c. 70. 1888.
('88) Scribner, F. L. and Viala, P. U. S. D. A., Bot. Div., Sec. Veg. Path. Bul. 7: l. c. 19. 1888.

is much reduced as compared with younger ones. The basal cells are longer than those of the pycnidium but of about the same diameter. The spermatia which are cut off from the tip of these cells have not nearly so great diameter. The basal cells lie very regularly and project from all sides of the spermogonium toward the centre and have the general appearance of the spermogonium of a Uredine. The spermogonium is sometimes as large as a pycnidium, though more often it is smaller. Great quantities of spermatia are developed and are forced out through the long ostiole which is developed at the apex.

It is very common to find pycnospores intermingled with the spermatia. (Plate III, Fig. 17.) The mature spermatium is a very small body. (Plate V, Fig. 37.) It measures .1 to .2 x .45 to .65 microns. In a liquid mount it has a dancing motion and for that reason one has difficulty in securing a drawing of it. In such a medium it appears to be dumb-bell shaped but in stained sections it is seen to be cylindrical but with densely straining substance in each end which, being very refractive, gives the dumb-bell effect. The writer has made frequent attempts to germinate spermatia in distilled and rain water and in sugar solutions but has never succeeded. These attempts have not only been made as the spermatia exude from the spermogonium but also after they had wintered over in an old mummy.

A great many conjectures have been made as to the function of these bodies. Nearly every worker has added to the list. Many have regarded spermogonia as vestiges of a male sexual stage. The opinion of Viala et Ravaz that they are a special conidium which will germinate only under special conditions and which serve for very wide and very rapid dissemination has already been noted. But this latter idea carries little weight, for spermogonia do not become abundant until August 1st, whereas that is about the time when fewer infections appear in the vineyard. In connection with what will be said in the next paragraph, the idea that the spermogonia are a vestigal male element seems more tenable than any others suggested. However, Cornu ('76), referring to spermatia in general, thinks this is not the case.

In the writer's investigations, he has never seen spermogonia on any part except the berries. Since he has found perithecia on leaf petioles it might be expected that spermogonia might also occasionally develop on such parts, but thus far he has never found them. Prunet ('00) records their occurence on leaves, stems, and elsewhere.

('76) Cornu, Max. Reproduction des Ascomycetes, Ann. Sci. Nat. 6me ser., 3: 53–112. 1876.

('00) Prunet, A. Rev. Vit. 13: l. c., 437. 1900.

Pycnosclerotia (Plate IV, Figs. 22 and 23.)

After the June and early July rains, infections on leaves and stems are not so common. In fact, they are rarely met with. On the berry, however, every rain of any duration or a shower followed by foggy weather permits of a new infection. Until about the first of August, pycnospores are produced in enormous numbers on the mummied berries. They are discharged with rain or dew and produce new infections if lodged in a favorable place and the moisture persists long enough. After about the first of August, on berries which show new spots, pycnidia as well as spermogonia develop in quantity. But on examination with the microscope, most of the pycnidia are found to be void of pycnospores, i. e., none are developed. In fact, such sporeless pycnidia are occasionally found earlier in the season. The development of the pycnidium is typical except that no basal cells are ever present. The whole interior fills up with a pseudoparenchyma of large cells which are gorged with a substance that in fresh condition appears whitish. These are the bodies, which, the writer understands, Viala et Ravaz call sclerotia. Some objection has been made to the use of this term and for clearness we shall call them pycnosclerotia.

Upon making thin microscopic sections of such pycnosclerotia, staining them shows that in the centre there are some cells which retain the stain much more tenaciously than others. (Plate IV, Fig. 23.) This recalls immediately the condition found in young perithecia in the early spring, and the writer is satisfied that they are identical. *The pycnosclerotium becomes the perithecium.* There are occasionally pycnidia developed on such berries which contain pycnospores but they are relatively scarce, but as has been pointed out above, pycnidia with pycnospores as well as spermatia are often found on the old mummies in the spring. The writer has also made note of the fact that it is relatively difficult to find perithecia with asci on berries which, from their size, had evidently rotted early the previous season. The simultaneous production of incipient perithecia (pycnosclerotia) and spermogonia in addition to the above facts might lead one to believe that late in the season the sexual stages appear and prepare for winter. And from this one might go a step further and conjecture that originally a trichogyne from the pycnosclerotium carried the male germ cell (spermatium) to the egg where fertilization was accomplished.

But, on the contrary, practically every author states that the pycnidia after producing pycnospores are transformed into perithecia. Among

these are the following: Prillieux ('88) writes "at first sight one recognizes such identity of form and aspect between these perithecia and the conceptacles of Phoma uvicola, one could not doubt that they appertained to one and the same fungus; but moreover, when one observes, as I have done in case of the latter, very numerous berries desiccated by Black Rot, he can not help but wonder at the very complete disappearance of the pycnidia which covered the affected berries in the autumn; but they are replaced by the perithecia. Have the pycnidia and spermogonia of which I have found not a trace disappeared to give place to the perithecial formation or have they only changed into perithecia during the winter? The latter supposition is the more probable and it is easily proven by a study of the ascosporous conceptacles, etc." Jaczewski ('00) writes: "the pycnidium can be changed at any time to the resting stage if the bunches are exposed to the cold or are dried," and a few lines later, "the pycnidium becomes in this manner a perithecium (Fig. 3)." The same opinion is held by Perraud ('99). Prunet ('97) thinks they may transform into perithecia, pycnidia, or spermogonia.

In a cluster of mummies taken late in the autumn or early winter, since practically all of the mummied berries cling to the pedicle, one can find all the various infections of the summer and these may be readily distinguished by the size of the mummied berry. The berry which rots early is represented by a much smaller mummy. On Dec. 1, 1908, the writer obtained a quantity of clusters of mummies from the vineyard, and on the early rotted berries (infection of June 22) he finds that the pycnidia (and only pycnospores were developed at that time) are now filled with a pseudoparenchyma and have the general appearance of pycnosclerotia. That they are the same, however, is a thing he has not yet determined. He is inclined to think they are not, first, for the reason cited above, and then from the following fact: berries which rotted from the infection of June 30, 1907, were kept in a screen in the vineyard suspended to a wire and protected by a vine until autumn and then were placed on the ground. In the spring these were brought in and placed on moist sand. Perithecia were never developed. However, the

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('88) Prillieux, Ed. Production de périthèces de Physalospora bidwellii au printemps sur les grains de raisins attaqués l'année précédent par le Black Rot. Bul. Soc. Myc. France 4: 59–61. 1888.

('97) Prunet, A. Les formes du parasite du Black Rot, de l'automne au printemps. Compt. Rend. Acad. Sci. Paris. 124: 250–252. 1897.

('99) Perraud, Joseph. Sur les formes de conservation et reproduction du Black Rot. Compt. Rend. Acad. Sci. Paris. 128: 1249–1251. 1899.

(00) Jaczewski, A. von. Uber die Pilze, welche die Krankheit der Weinreben "Black Rot" verursachen. Zeitschr. Pflanzenkr. 10: 257–267. 1900.

writer did not carry alongside of these, mummies of a later infection which did develop perithecia.

Conidia (Plate IV, Fig. 24 and Plate V, Fig. 38.)

Viala ('93) records the occurrence of a conidial stage on mummies which have been left on the ground. He also figures them. (His Fig. 56.) The appearance of the conidiophores suggests a Penicillium. It seems to be the generally accepted opinion that this is a Penicillium and of no organic connection with the Black Rot fungus. But a number of workers believe they have seen free external conidia developed. These are of two kinds: those developed from the perithecial wall on the wintered mummy and others developed from the pycnidial wall on the freshly rotted berry. Scribner ('86) in a foot-note quotes from Erwin F. Smith as follows: "these (the conidia) are usually borne on conidiophores arising from that part of the perithecium which bursts through the epidermis of the berry. I found them very often in this situation but nowhere else on the berry, and was slowly forced to believe them a part of the Phoma, though I could not entirely satisfy myself."

The writer has not been so fortunate in finding conidia developed on the old mummy. He has made frequent, careful searches for them but has rarely succeeded in finding them. On June 11, 1909, he found bodies which he thought might be interpreted as conidia, while on the 27th, he found some apparently unmistakable instances from which he has made drawings shown in Plate V, Fig. 36.

Regarding the development of conidia on the freshly rotted berry, Scribner ('86) writes: "I am confident that I have seen upon completely diseased berries gathered from the vine, but more particularly upon similar berries kept in a moist chamber for a few days under a bell-jar, the conidiophores of Phoma, bearing imperfectly developed conidia. They appeared to be growing from the exposed portion of the pycnidia, but whether from these or from specially developed sclerotia I am not prepared to say." The same author ('87) also claims to find them abundantly after rainy weather. Delacroix ('01) describes a conidial stage developed on the conceptacles (pycnidia) and again ('02) empha-

('86) Scribner, F. L. Report on the fungus diseases of the Grape Vine. U. S. D. A., Bot. Div., Sec. Plant Path. Bul. **2**: l. c. 32. 1886.

('86) Scribner, F. L. Black Rot-Physalospora bidwellii Sacc. Proc. Soc. Prom. Agr. Sci. **7**: 82–88. 1886.

('87) ———, ———. Report of the Mycologist for the year 1886. III. Black Rot. Ann. Rept. U. S. Dept. Agr. for 1886: 109–112. 1887. pl. III.

('93) Viala, P. Les maladies de la vigne. Troisième édition. Montpellier. 1893. l. c. 186.

('01) Delacroix, G.. Sur une forme conidienne du Champignon du Black Rot, Guignardia bidwellii. Bul. Soc. Myc. France. **17**: 133–135. 1901, and Compt. Rend. Acad. Sci. Paris 132: 862–864. 1901.

('02) ———, ——— ibid. 2e communication. Bul. Soc. Myc. France **19**: 128–132. 1903, and Compt. Rend. Acad. Sci. Paris 135: 1732–1734. 1902.

sizes the fact and describes infection experiments. Numerous other authors refer to conidial development.

Expecting to find such bodies, the present writer has made a great many observations on berries in different stages of mummification from rot, during the entire summer and under all conditions both in the laboratory and in the field, but he has never yet seen an object which he could interpret as a conidium. The nearest approach that he has seen was in the case of some berries put in a moist chamber and examined July 10, 1908. On that date he wrote in his notes: "a few days ago rotted berries were placed in a moist chamber. The pycnidia matured and produced spores which oozed out in a little white ball or sometimes in a chain. But in addition to this, nearly every pycnidium was seen to have a stellate fringe of grayish white hyphae about it. Under the microscope these appear to be simply threads of mycelium which have grown out from the pycnidium. I can find no evidence that they are conidiophores which bear external conidia." Some of this material was dropped into Gilson fixer* and carried through carefully in order that none of these bodies should be broken off. That the writer was successful can be seen from the photomicrograph. (Plate IV, Fig. 24.) However, in examining the fresh material or a series of such sections he has never seen a well-developed conidium in any case.

Pure cultures of the Black Rot fungus

On July 1st, 2nd, 3rd and 4th, 1907, numerous asci containing ascospores were transferred from poured plate dilutions to sterilized grape stems in the hope of thus obtaining pure cultures. Previous to this, the writer had tried to transfer germinated spores but had rarely been able even to obtain spore germination. As he now knows he did not give sufficient time, and more than that, saprophytic forms which grew so much more rapidly overran and obscured any spores which did germinate. In the case of the transferred asci, he found in ten days a few of the tubes which showed a blackish gray mycelial growth. At the end of three weeks there were ten tubes, apparently all pure cultures, which had similar mycelium. Some of the tubes had developed pycnidia which contained pycnospores, very evidently those of the Black Rot fungus.

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*A modification of the original Gilson fixer, sometimes called Harvard fixer, prepared as follows:

95% alcohol	42 cc.
Acetic acid (glacial 80%)	18 cc.
Mercuric chlorid (sat. sol.)	11 cc.
Nitric acid (conc.)	2 cc.
Water	60 cc.

Fix six to twelve hours and wash in 70% alcohol.

But when the writer came to experiment with the discharge of ascospores, this suggested another means of obtaining pure cultures. A plate of agar was poured and allowed to harden. It was then inverted over a bunch of mummies containing mature asci and the mummies were then made wet with water. In an hour quantities of ascospores were shot to the agar and adhered there. Since no other organisms were present, the spores could be left until they had time to germinate. Such quantities of spores were present that there was no difficulty in distinguishing with the microscope that these were the Black Rot ascospores. In poured plate dilutions this was practically impossible and it was even necessary to wait until the spore had germinated before it could be located with any degree of certainty. Transfers of such ejaculated spores to sterilized stems gave the characteristic growth in ten days. In this way, the writer was able to obtain pure cultures from ascospores at any time during the summer.

Another method of obtaining pure cultures of the fungus which was sometimes employed by the writer was to break open a rotted berry before it had wrinkled down and remove with sanitary precautions a small block of the infected tissue to a sterile medium. In this way pure cultures were obtained from berries which were rotted completely as well as from those which developed only a superficial black crust, and they appeared identical in every respect.

Also by transferring, with a sterile needle, pycnospores which had oozed from a pycnidium (readily obtained by floating a slice of rotted berry on a dish of water), the writer has often been able to obtain pure cultures of the fungus. In plating pycnospores, he has rarely had success in getting cultures largely because of the very small size of the pycnospores and the difficulty in certainly locating them in the medium.

The object in getting pure cultures was to obtain absolute proof of the connection of the various stages of this fungus as well as to have material for infection experiments. Regarding the former he can only record confirmation of the identity of the pycnidial stages on leaf, stem and berry with ascosporous stage on mummies. This confirmation is based on the morphological identity of mycelium and pycnidia developed from these sources. The writer has not found spermatia developed in these cultures nor obtained cultures with them, but the connection of this stage with the cycle of development has been established previously in another way. He has obtained pycnosclerotia in culture and had expected to obtain perithecia and asci by wintering such cultures and then putting them in a favorable place for development in the spring. This has been

accomplished by Jaczewski ('00). But of the thirty or more cultures thus treated none developed perithecia with asci.

Infection experiments

Viala et Ravaz ('88) claim to have demonstrated the connection of the various stages of the Black Rot fungus by means of cultures. Speschnew ('99) and Jaczewski ('00) describe infection experiments to determine the pathogenicity of Phoma reniformis (Guignardia reniformis, a form scarcely or not at all distinguishable from G. bidwellii), which were successful. Prunet ('98) describes in detail the method of studying infections both as to time and to manner. He describes the lodgment and germination of the spore and the entrance of the germ-tube. Soursac ('08) describes studies in resistance of various species of *Vitis* to Black Rot in which spores were sown on leaves and fruits and the degree of susceptibility determined by the number and size of the spots and by the length of the period of incubation. Obviously many infections were obtained. The writer had not anticipated any difficulty in producing infections and at first was concerned more in determining the exact method of entrance of the germ-tube.

On June 24th, 25th and 28th, July 1st, 2nd, 3rd, 5th, 9th and 10th, 1907, inoculations were made on leaves, stems and pedicles, and on the later dates on young fruits. Some of these inoculations were made indoors in moist chambers but many were *in situ,* the inoculated part being protected by a lamp chimney plugged with cotton. These had been put on ten days to two weeks previous. Further details are not necessary since in the experiments indoors the writer was never able to produce a lesion nor find in thin sections, either tangential or cross, the entrance of a germ-tube; and, although on those out of doors occasional infections appeared on inoculated clusters, on the other hand, checks were not entirely free from infection. On July 19, 1907, we wrote in our notes: "a pair of leaves inoculated July 1, show presence of Rot. The older leaf was inoculated on the under side only; no infection. The smaller on the upper side only; a great many infections were produced and the spots have run together, making large blotches. However, the check is not entirely free, but has

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('88) Viala, P. et Ravaz, L. Recherches experimentales sur les maladies de la vigne. Compt. Rend. Acad. Sci. Paris 106: 1711–1712. 1888.

('98) Prunet, A. Observations et expériences sur le Black Rot. Rev. Vit. 9: 1. c. 625. 1898.

('99) Speschnew, N. von. Uber Parasitimus von Phoma reniformis V. & R. und seine Rolle in der Blackrot-Krankheiten der Weintraube. Zeitschr. Pflanzenkr. 9: 257–260. 1899.

('00) Jaczewski, A. von. Uber die Pilze, welche die Krankheit der Weinreben "Black Rot" verursachen. Zeitschr. Pflanzenkr. 10: 257–267. 1900.

('08) Soursac, L. Recherches sur le Black Rot. Ann. l'École Nat. Agr. Montpellier. 8: 151–160. 1908

a single spot on it." This was under a lamp chimney as described above.

During this time, infection experiments indoors were continued on young berries in a moist chamber. Examination had shown that berries were better for this purpose than leaves, as there was less masking material present in the host cells. No germ-tubes were found entering the berry and inoculated clusters left a month in the moist chamber never developed Black Rot lesions. This occurred, notwithstanding the fact that both ascospores and pycnospores were found germinating in abundance on such berries and the drops of water in which they were started often did not evaporate for three or four days.

On June 20, 1907, one vine was completely enclosed with cheese cloth which was stretched over a frame. A series of inoculation experiments were started on the green parts of the vine. "The vine was not entirely free from rot but relatively so. The few rotted berries or spotted leaves were carefully picked off. On one side of the vine the berries of the cluster were painted with ascospores and on the other with conidia. Young leaves and shoots were also inoculated. After painting on the spores with a camel's hair brush all parts were sprayed with a fine mist of clear water from an atomizer." Lower clusters and leaves were selected at first and every evening about sundown for ten days two or more clusters of berries were inoculated as described above. Once a bit of the cuticle and epidermis was shaved off of every berry on two clusters and the two kinds of spores introduced into the soft juicy parenchyma. All inoculated clusters were tagged. After a month there were no infections that could be attributed directly to inoculations. Occasional berries rotted but these were as common on the upper uninoculated clusters as on the inoculated ones. None of the injured berries which were inoculated became infected, the wounds healing over to a certain extent. Tests were usually made of the spores to see that they were viable. Drops of water were also found between the berries the following morning on several occasions.

The season of 1907 ended with no definite knowledge of the exact method of entrance of the germ-tube and with no absolute proof that the organism found constantly associated with diseased parts was the cause of the disease. On the face of it this seemed absurd. Consequently, in 1908, the writer undertook primarily to determine these two facts and to make such other observations as were possible. With the experience of 1907, new precautions and some new methods were employed. Many thousand inoculations were made on berries as well as leaves and stems, yet at the end of the second season the writer could record only that he had never produced a characteristic lesion of Black

Rot on fruits and had never seen the entrance of the germ-tube. In one case infections on leaves similar to those of 1907 were produced, but they were not under such rigid control of external conditions as were those of 1907.

Believing that there must be some slight mistake in technique which was discounting all his results, he was very glad of an opportunity on July 17, 1908, to go over the whole matter very carefully with Prof. Whetzel, and the same day to receive suggestions from more than a dozen horticulturists, members of the Graduate School in Agriculture, who sought shelter in his field laboratory because of rain. Such suggestions as they made, which had not already been tried repeatedly, were incorporated into his experimental work the same day — a most favorable one because of moisture conditions. It is not necessary to insert details since all results were negative. One experiment may be of interest, however. During a rainy period, July 18, 1908, pycnospores, which as shown by contemporaneous tests were capable of germination, were accumulated from berries and placed in a dish of fresh rain-water. A small drop of the spore-laden water was touched on every berry, or in the drop of adhering water between two berries, of numerous clusters. Approximately 600 inoculations were made. A tent was stretched over the vine to prevent rain from washing spores away. This was at 5 P. M. The night was foggy and perfectly still and at 9 A. M. the following day many of the drops were just as he had placed them the evening before. He had hoped only to produce a preponderance of rot on inoculated berries since numerous infections were undoubtedly taking place naturally. However, after three weeks, he found that uninoculated clusters on the same and adjacent vines actually had more recently rotted berries in them than on the ones which had been inoculated. In fact those inoculated clusters at picking time were the best in the vicinity. The writer is utterly at a loss to understand his failures to obtain infections.

PATHOLOGICAL HISTOLOGY

Leaf

A study of stained sections of leaves bearing very young spots shows that the first effect of the fungus on the tissues of the leaf is to kill the cells (necrosis) and cause a collapse of the spongy parenchyma. (Plate V, Fig. 39.) The original of this figure is a section of a spot bearing a few pycnidia. The mesophyll is shriveled and dried until it can be recognized only by comparison with adjacent healthy tissue. The palisade layer retains approximately its original size and position, but the cells are evidently inactive and dead. It will be noticed also that

the limit of the spot is a vein. This is practically always the case, although often the vein is a small one. This has been noted previously in another connection.

Stem

The lesions are confined to the cortex, rarely extending as deep as the cambium layer. Details of the histological changes can be seen from the photomicrograph (Plate IV., Fig. 20).

Berry

The author has made very careful study of the successive histological changes which take place in the rotting of the berry. Notes were made from fresh material, but at each stage material was also killed and fixed. Microtome sections have been made and the studies on fresh material corroborated. The following description is compiled, often verbatim, from notes made on fresh material:

'08–vii–3–2 P. M. When the spot is 1 to 2 mm. in diameter and the ring just appearing there are evidences of histological changes. "The epidermal cells become opaque (in sections), i. e., cut off all the light and are filled with some granular brown substance. The cells of the hypodermal parenchyma immediately beneath the epidermis are slightly flattened and occasionally some of the larger parenchymatous cells are also slightly flattened. The change is noticeable five or six cells deep at the centre of the spot, but the diseased area is saucer shaped. The chlorophyll granules, while still present, are not arranged regularly about the periphery as in the healthy cells, but lie in an irregular mass. The cells of the diseased area seem to be thicker walled and darker. This is due to the presence of intercellular mycelium."

'08–vii–3–3 P. M. "Sections of spots 3 to 4 mm. in diameter which appear with a distinct aureole show further changes. The plasma membrane had turned dark colored or brown and adheres closely to the wall instead of being light colored and spread out some distance into the cell. The chloroplastids are also drawn close to the wall and lose their color. A yellowish brown coloring matter slowly diffuses away from them. These changes make the cell walls and in fact all of the diseased area appears darker than the normal tissue. The depth to which the fungus has penetrated is quite evident in a cross-section by a distinct band of yellowish brown substance found in a stratum of yellowish brown cells one to three cells wide. These are the first larger cells of the parenchyma which make up the bulk of the berry. As compared with these large host cells, there is a relatively small amount of mycelium present, but it is quite easily distinguished by its staining reactions, becoming a bright pink with eosin. The writer has found hyphæ extending down as far as the yellowish stained line but never further."

'08–vii–3–4:30 P. M. "The spots are 4 to 5 mm. in diameter, and the flattening of the berry is apparent to the naked eye. The brownish aureole is 1 mm. wide now. The centre of the spot is still whitish as at the beginning. Microscopically the changes have been simply progressive. The cells near the surface have not flattened to any extent but several layers of cells deeper the flattening is more pronounced than at any other point. In this same region, too, the contents of the cells have now turned slightly brown and fill the whole cell, thus making a rather definite band for two or three cells in width and saucer shaped. All the cells of the diseased area appear darker than the healthy ones and appear to have thicker walls."

'08–vii–3–8:30 P. M. "General appearance much the same. Spots are 5 to 6 mm. in diameter and the aureole slightly wider. A collapsing of the band of deep seated cells is apparent. Mycelium is present about these cells but not abundant; it is mostly intercellular; can be found laterally as far as the edge of the spot, just under the cuticle, and entad as far as the flattened band but not in the cells of the band."

'08–vii–4–5 A. M. "Spots are 6 to 8 mm. in diameter and the aureole 2 mm. wide. Spot is not only flattened but often depressed at the centre. The band of deep-seated cells which collapsed during the night has flattened down, others having been added from the ental side and the layer of cells between them, and the epidermis has flattened also, thus making a depression. Between this now brownish black band (the cells have become so compact as to cut off nearly all the light) is a funnel or saucer-shaped area of cells which have the general appearance of those where the spot was very young; thicker walled, darker, slightly collapsed."

'08–vii–4–9:30 A. M. "Now the spots are 8 or 9 mm. in diameter. The aureole has increased in size or in some cases there begins to appear an outer darker band and an inner lighter brown one, while in others there is a lighter line between them. Thus the aureole has two or three bands or rings to it. Conditions have not changed internally to any material extent. A few more layers of parenchyma have been added to the deep band, these entirely from the ental side. The layer of cells between these and the epidermis, though somewhat flattened, remain practically unchanged. Mycelium, both intercellular and intracellular, is abundant there and in the dense layer it can occasionally be detected in favorable sections."

'08–vii–4–2:30 P. M. "Spots are not much larger than in previous observation but if so the outer browner band of the aureole has widened. Internally perhaps only one point is noticeable as distinct from previous observations. The tissue for considerable distance beneath the deep-

seated band appears diseased. The contents of the cells is evidently killed, is plasmolized to some extent, and lies as a bulky irregular mass in the cells. This condition extends inwardly in the shape of a funnel as far as the seed."

'08–vii–4–6:30 P. M. "The spot has increased slightly in size and has gone perhaps a little deeper, otherwise there seems to be no change."

'08–vii–5–5:30 A. M. "Several changes have taken place. The spots are a centimetre or more in diameter, and some involve a third of the berry. Where two spots are close together, half the berry is destroyed. A dozen or more brown specks on the white centre of the spot mark the beginning of formation of pycnidia. The cells between the deep-seated band and the epidermis have flattened down until they are quite dense. The cells between these and the seed have collapsed and rapidly add to the already broad band. The diseased condition extends to the seed and around it on either side, but I cannot be sure that the fungus enters the seed."

'08–vii–5–10:30 A. M. "Spots involve one-fourth to one-half the berry. Pycnidia become more prominent. Those first to appear now turn blackish and a great many more appear. Tissue as deep as the seed has collapsed. That tissue between the deep-seated layer and the epidermis has not entirely flattened out even yet."

'08–vii–5–4 P. M. "At this time the rotted clusters are very apparent on the vine. The spots which were hidden at first have worked around so as to be apparent from nearly any aspect. They are becoming quite distinctly blackish. The whole aureole is now a purplish brown color and the pycnidia are covering both the central pale spot and the inner light brown ring of the aureole. The spots are strongly flattened and depressed at the centre. The stratified mass of collapsed cells lies flat on the seed."

'08–vii–5–9:30 P. M. "Half the berry is involved. The spots are considerably darker and the pycnidia more numerous."

'08–vii–6–8 A. M. "Berries are turning black. Those infected more than once are entirely brown, and black pycnidia cover as much as half of some. The pulp has wrinkled down so that the seed forms a skeleton. Now there is a solid thick skin made up of the walls of collapsed cells."

CONTROL

(Figs. 143, 144 and 145.)

The bordeaux mixture was just being perfected by Millardet and others in France, for the control of Downy Mildew, when the Black Rot first appeared there. Naturally the use of the mixture was at once extended to a control of the Black Rot, and almost from the first

success was reported by the experimenters. The early history of the rise of spraying as a means of controlling the Black Rot is given in detail by Lodeman ('96). In reviewing the literature on the subject one finds that by far the greater part of the work done and reported upon has been a study of the means of control of the disease. Indeed, the writer feels that too much attention has been given to this phase of the subject and that it is for this reason that we have not sooner arrived at a rational basis for the treatment of the disease.

In spite of the continued reports of successful treatment of Black Rot made by the Department of Agriculture in France, we may believe that practically the success was not always so great. Indeed, occasional note of the fact has been made. Caneout ('97) discounts the experi-

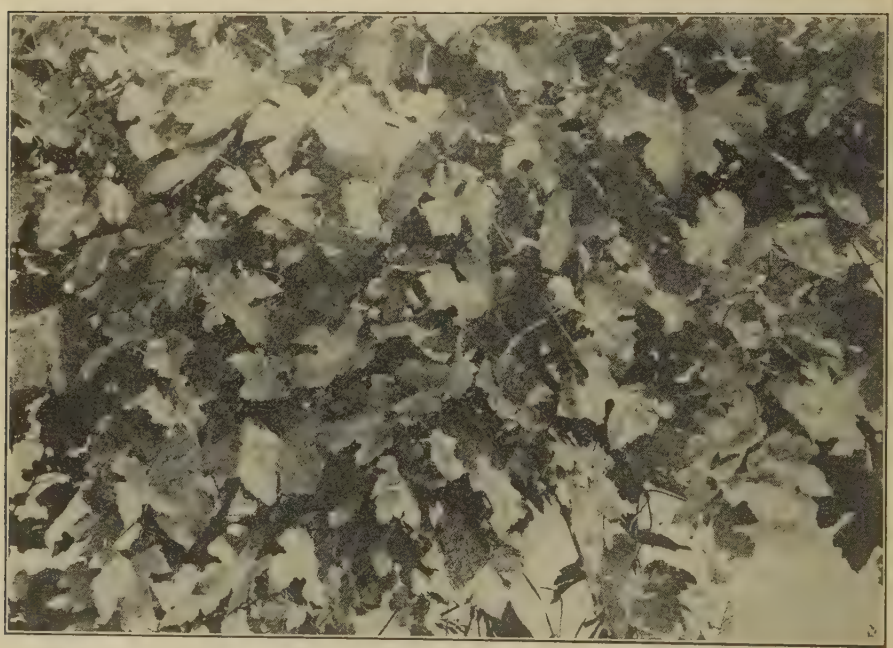

FIG. 143.—*Photograph of a vine in the experimental plats at Romulus, N. Y., in 1908. The mass of foliage makes it difficult to spray the clusters. See the same vine in Fig.* 144.

ments of Prunet and of Lavergne carried on under the direction of the Minister of Agriculture. An excursion was organized to visit the experimental plats, and while most of the party agreed that the experiment was a success, Caneout remained skeptical. He admits that the

('96) Lodeman, E. G. The Spraying of Plants. New York. 1896. The MacMillan Co. Last Edition, 1906.

('97) Caneout. La lutte contre le black-rot dans le Sud-Ouest. Prog. Agr. et Vit. 28: 201–206. 1897.

Rot was partially controlled, but that it took ten to twelve sprayings to do it. He also states that M. Goulard lost forty per cent. of his fruit after twelve sprayings. He cites losses of twenty to one hundred per cent on fourteen of Prunet's experimental plats, some of which were sprayed as high as ten times. Also ('95) Prog. Agr. et Vit., answers to a circular letter were published. The letter contained two questions *, the latter a request for information whether in less disastrous seasons the salts of copper have not given satisfactory results. Some say emphatically that they have not. Again ('97) in the same

FIG. 144.— *Same vine and from same position as in Fig.* 143, *but with leaves picked off. Shows average yield of vines and effectiveness of spraying. Compare with Fig.* 145.

journal there appears a title, " Insuffisance pratique des sels de cuivre contre le Black Rot." Letters from different sources are published showing that practically the Rot had not been successfully controlled.

But these experiments of Prunet, continuing from year to year a

* Nous nous demandons si nous ne nous trouvons pas en présence de faits analogues en ce qui concerne le Black-rot? Et si, dans les saisons moins désastreuses, les sels du cuivre ne donneront pas de nouveau des resultats enregistrés depuis dix ans?

('95) Anonymous. Le Black Rot et les sels de cuivre. Prog. Agr. et Vit. **24**: 81–88. 1895.

('97) Anonymous. Insuffisance pratique des sels de cuivre contre le Black Rot. Prog. Agr. et Vit. **28**: 145–149. 1897.

series of so-called fractional treatments, finally led to a more complete understanding of the method of control of the disease. These fractional treatments are fully described by Prunet ('05). Essentially they consisted of laying out a big plat, a few rows of which were added to the sprayed list each day. In this way Prunet was able to determine on just what day infection had actually taken place. In 1897, he announced that "a treatment immediately after an invasion protects against the *succeeding* invasion." From this, step by step, Prunet finally demonstrated that each and every infection was directly traceable to a rain of some duration or of a rain followed by fog. This was a great step and one which we are slow to appreciate.

In the present author's experience, he has found that all infections of any consequence are directly dependent on the meteorological conditions. In the vineyards at Romulus, he has observed, and the fact is recorded in his meteorological data, that at intervals throughout the summer we are reasonably sure to have a rainy period of one to three days' duration. The actual precipitation may be slight but in such cases there is usually fog and cloudy weather. He has already shown that the spores of this fungus are discharged by a mechanical process only in the presence of precipitated moisture and that they must have moisture in which to germinate. And since each berry that rots represents a separate and new infection from the outside it becomes apparent that if some toxic substance can be interposed between the berry and the spore which will prevent germination, the fruit will be saved.

It is astonishing to one following through all the various literature on the control of the Black Rot to find what an enormous number of spray mixtures have been tried and how extensive the operations have been. One feels pretty well convinced after a review of the literature that of the common or even more rare toxic salts, none of them is more efficacious in the control of Black Rot than the salts of copper or, for that matter, the bordeaux mixture. Ravaz et Gouirand ('96 and '97) have tested the actions of solutions of very many salts on the germination of Black Rot spores, and have tested in practice those which gave promise of being valuable. In 1897 a report is given of Black Rot spore germination tests in eighty-four different salt solutions each in nine different strengths. A number of the solutions when tested in practice gave results but none were so good as the bordeaux mixture.

('96) Ravaz, L. et Gouirand, G. Action de quelques substances sur la germination des spores du Black Rot. Compt. Rend. Acad. Sci. Paris, 123: 1086–1088. 1896.

('97) ———, ———. Recherches sur le traitment des maladies de la vigne. Rev. Vit. 7: 305–313; 338–340. 1897.

('05) Prunet, A. Recherches nouvelles sur l'evolution du Black Rot. Rev. Vit. 24: 581–583; 664–666. 1905.

It should be noted, however, that these tests were made in solutions of the various salts. When such a substance is sprayed onto the foliage and exposed to the action of the elements, chemical changes often occur. Some such substances would be injurious to the foliage and could not be used at all. Others are very soluble and would be washed off at once by rain, while others, which might be quite insoluble, have no adhesive properties, and would be worthless for that reason. It seems questionable, therefore, whether such tests are of practical value. Reddick and Wallace ('10) have suggested this with reference to disease control and have suggested a substitute method, while Wallace, Blodgett, and Hesler

FIG. 145.—*Photograph of a vine in next adjacent row to one shown in Fig.* 144. *Unsprayed.*

('11) have taken up the question in detail with reference to three plant-disease producing organisms.

From what has just been said it is apparent that, to be effective against the Black Rot, a spray substance should be one which does not

('10) Reddick, D., and Wallace, E. A laboratory method of determining the fungicidal value of a spray mixture or solution. Science n. ser. 31: 798. 1910. Paper read at the First Annual Meeting of the Am. Phytopath. Soc. at Boston, Mass., Dec., 1909.

('11) Wallace, E., Blodgett, F. M., and Hesler, Lex R. Studies of the fungicidal value of lime-sulfur preparations. N. Y. (Cornell) Agr. Exp. Sta. Bul. 290: 1911.

injure the vine, which is relatively insoluble in meteoric water, and which adheres well to foliage and fruit. Of all the substances thus far tested for controlling Black Rot none has given as good results in practice as the bordeaux mixture.

Bordeaux mixture

The chemical nature of this substance has been the subject of extended investigation by Bedford and Pickering ('09). The reactions occurring in its preparation are far from simple and need not be a matter of consideration at this place. When the sulfate of copper is combined with milk of lime, a peculiar greenish white precipitate is formed which is highly insoluble in water. The exact chemical nature of this precipitate is very complex and it is known to vary greatly, depending on slight variations in the method of preparation. This precipitate, when kept in suspension and applied to the foliage and fruit under high pressure and through a nozzle with a small hole in the disc, forms a thin film over all parts of the vine. Upon evaporation of the water the precipitate is left in a relatively insoluble state on the leaf or fruit and adheres tenaciously. Kelhofer ('07) has shown that bordeaux mixture properly made and applied will be only slightly washed away even after a continued rain of twenty-four hours. It would seem that the particular efficacy of this substance lies in the fact of its relative insolubility in water.

Crandall ('09) has shown that small amounts of copper come into solution at once when a drop of meteoric water is placed on a recently bordeaux-sprayed leaf, and is of the opinion (l. c. 261) that the concentration becomes sufficient to prevent germination of spores of apple-infesting fungi. Schander ('04), on the other hand, believes that the germinating fungous spores excrete a substance which brings the copper into a solution of killing strength. Wallace, Blodgett, and Hesler ('11) have recently presented some evidence in favor of the latter view in connection with spores of *Sclerotinia fructigena*. The writer has not made an investigation of this point in connection with *Guignardia* spores.

('04) Schander, Richard. Uber die physiologische Wirkung der Kupfervitriol-kalkbrühe. Landw. Jahrbucher 33: l. c. 518–526. 1904.

('07) Kelhofer, W. Uber die Ausführung und die Ergebnisse von Haftfestigkeitsversuchen Kupferhaltiger Bekämpfungsmittle gegen die Peronospora. Zeitschr. Pflanzenkr. 17: 1–12 1907.

('09) Duke of Bedford and Pickering, S. U. Copper Fungicides. Woburn Exp. Fruit Farm Rept. 11: 1–191. 1909.

('09) Crandall, Chas. S. Bordeaux Mixture. Ill. Agr. Exp. Sta. Bul. 135: 200–296. 1909.

('11) Wallace, E., Blodgett, F. M., and Hesler, Lex R. Studies of the fungicidal value of lime-sulfur preparations. N. Y. (Cornell) Agr. Exp. Sta. Bul. 290: 1911.

Climatic conditions

But even granting that bordeaux mixture applied to the actively growing parts and fruits before rains will prevent infection, the practical man immediately asks how we are to know when the rain is coming and what he is going to do when there are hundreds of acres to spray. This inquiry has been answered to the author's satisfaction by Wilson and Reddick ('09). In the first place, one must be a close student of local weather conditions. By studying available weather data in the daily papers and weather bulletins one can predict in a general way the time when storm periods are due. The writer found during the summer of 1908 that he was able to do this, and with one exception we did our spraying on the experimental plats before a storm period. The one exception, however, was not a fault of the prediction, but of the spray machinery.

In spraying a large acreage the operator should know after a few sprayings how many days are required to spray the entire vineyard. Inspection of the weather records will show that during June there are rarely more than six days, more often only four or five, when an effective application can be made. If the whole vineyard can not be sprayed in five days it is a sure indication that there is not sufficient machinery for the proper execution of the work.

The question is often asked as to what should be done should an anticipated rain fail to materialize. The writers just mentioned have cited a case (l. c. 394) in which spraying done June 15th was almost completely effective in preventing infections coming with the prolonged rain on June 22d, 23rd, and 24th. Here were seven days of protection at the time of the year when the vines are making very rapid growth. How much longer the spray would have continued effective is a question. New leaves are developed throughout the season and unfolding leaves present unsprayed area. Berries increase in size very rapidly and thus expose new surface. On June 15th, in the case just cited, the vines were past full bloom, but the calyces were clinging to a few of the clusters. The young berries had undergone growth of a week, yet enough spray was still present on them to prevent infections. Adjacent unsprayed vines showed a large amount of rot from this infection.

Sanitary measures

Anything which will help to eradicate the fungus in its winter quarters will be of importance in the control of this disease. To this end it is of great importance that the mummied berries be destroyed. They may be carried out at picking time and separated in the packing house,

('09) Wilson, C. S., and Reddick, D. The Black Rot of the Grape, and Its Control. Second Report. N. Y. (Cornell) Agr. Exp. Sta. Bul. 266: 390–412. 1909.

since many of them cling to the cluster. Even if the clusters are only pulled off and thrown to the ground, an early spring plowing, thoroughly done, will turn under and destroy many of these sources of infection. Reddick and Wilson ('08) have shown that burning off the clinging tendrils from the wires, although destroying many sources of infection, is not a profitable investment and naturally the lesions can not be removed nor the fungus killed on the canes which are put up. There may eventually be a device perfected which will strip the clingers from the wires effectually, but none is known at present.

Some sanitary measures may be taken in respect to the general con-

FIG. 146.— *Bagging on a commercial scale. Bagging is no longer considered a protection from Black Rot. These grapes were sprayed four times before the bags were put on.*

ditions of the vineyard. It is highly desirable that good soil drainage be maintained to reduce the amount of surface moisture. This will allow a more rapid drying of dew and rain. Air drainage is also of much importance. A good circulation of air dries up drops of water and thus prevents germination of spores and infections. The writer believes that the explanation of the relative immunity of the vines in the Chautauqua belt to the Black Rot and other fungous troubles lies in the fact that they have such good natural air drainage. There is a constant flow of

('08) Reddick, D., and Wilson, C. S. The Black Rot of the Grape and its Control. N. Y. (Cornell) Agr. Exp. Sta. Bul. 253: 368–388. 1908.

air to or from the lake at all times and the currents set up help greatly to keep the leaves dry. Vineyards on hillsides do not suffer from lack of air drainage but those on the level and in the valleys do. Better air drainage may be effected to a certain extent by higher pruning and by training the canes in wider fans; in the case of the Kniffen system of pruning, by taking care not to leave too many spurs in the crowns. Fruit on shoots from such spurs is usually inferior at best.

Weeds are also a detriment to good air drainage, but in addition, help to conserve moisture and thus favor the fungus, to say nothing of their detriment as users of valuable soil moisture.

Spraying

Sanitary measures are to be directed against the fungus while in its winter quarters. When spring infections on leaves have taken place, the opportunities for further infection have been increased several thousand times. The important thing at this stage is to prevent new infections. Very thorough spraying in the manner suggested above will practically prevent such infections, as shown by Wilson and Reddick ('09). In this way tendrils and canes, as well as fruits, may be kept free from the disease, so that in a few favorable years the disease might be easily eradicated. The present writer believes this to be the key to the whole situation. If the growers will take advantage of such favorable years as we have had in 1907 and 1908, and practically free their vineyards from all sources of infection, they will have little difficulty in controlling the disease even in very rainy seasons. But if, on the other hand, the spraying is neglected in the drier years, we may expect to see a recurrence of Black Rot epidemics in the very wet years. The writer does not believe that spraying can ever be abandoned, though it may be somewhat reduced, and he does think it should be incorporated as one of the regular vineyard practices.

METEOROLOGICAL DATA TAKEN AT RAYMOND VINEYARD, ROMULUS., N. Y., JUNE 1st TO AUG. 17th, 1907.

Date	Temperature		Precipitation			Direction of prevailing wind	Character of day	Miscellaneous
	Max.	Min.	Time of beginning	Time of ending	Amount			
June								
1	57	52	—	—	—	SE	.1	
2	54	46	2:50	5	—	SE	1.	
3	78	50	—	—	—	SW	.1	
4	68	58	7.30 p. m.	—	—	S–SW	.5	
5	62	52	9.30	9 p. m.	—	SE	.9	hail at noon.
6	58	50	—	—	—	W–NW	.2	
7	68	50	—	—	—	W–NW	.8	

('09) Wilson, C. S., and Reddick, D. The Black Rot of the Grape and its Control. Second Report. N. Y. (Cornell) Agr. Exp. Sta. Bul. 266: 390–411. 1909.

METEOROLOGICAL DATA TAKEN AT RAYMOND VINEYARD, ROMULUS., N. Y., JUNE 1st TO AUG. 15th 1907 — *Continued*

Date	Temperature		Precipitation			Direction of prevailing wind	Character of day	Miscellaneous
	Max.	Min.	Time of beginning	Time of ending	Amount			
June								
8	66	53	—	—	—	E	.1	
9	63	56	—	—	—	W NW	.1	
10	66	48	—	—	—	SE-SW	.1	
11	70	52	—	—	—	SE	.5	
12	72	52	—	—	—	E-SE	.1	
13	58	51	—	—	—	E-SE	.5	
14	68	51	6	9	T	SW-W	.3	
15			—	—	—	W	.2	
16	80		—	—	—	W	.1	
17	84	70	—	—	—	NE-E	.1	
18	87		—	—	—	N-NE	.2	
19	74	72	—	—	—	SE	.5	
20	82	60	3.30	4	T	N	.9	
21	83	61	†	—	—	E	1.	foggy in a. m.
22	80	72	3	night	—	E	.6	
23	85	68	4	night	—	SW	.4	thunder shower.
24	80	68	12	1 & night	—	S	.4	
25		70	11	12	T			
26			10	2		W	.8	showers.
27			—	—	—	W	.4	high wind.
28			—	—	—	W	.1	
29*			p. m.				.5	
30			rain	all day			1.	
July								
1			6.30		T	SE-S	.9	
2			—	—	—			
3			—	—	—			
4			—	—	—			
5			—	—	—			
6			—	—	—			
7			—	—	—			
8						SW-W		
9	78		—	—	—	W-NW	.2	
10	83	69	—	—	—	W	.1	
11	74	59	8	—	—		1.	gentle rain all day.
12	74	58		7 a. m.	.88	W-NW	.7	showers at intervals.
13	80	53	—	—	—		.1	
14	83	58	—	—	—		.1	
15	85	62	—	—	—	SE	1.	
16	90	65	—	—	—	S SW	.7	hot and muggy.
17	89	70	showers		T	SW-W	.7	hot and muggy.
18	85	67	—	—	T	W-NW	.4	few drops in a. m.
19	87	57	—	—	T	NW	.1	
20								
21								
22			a. m.		.1	W	.7	
23	80	63	night	a. m.	.1	NW	.5	
24	86	58	—	—	—	—	—	
25	86	58	—	—	—	—	—	
26	80	58	4 a. m.	6 a. m.	.15	NW	.5	strong wind.
27	78	56	—	—	—	NW	.1	
28	84	55	—	—	—	NW	.3	
29	89	57	6 p. m.	—	T	W	.5	
30	80	56	evening		T	W	.6	
31	88	56	—	—	—	W-NW	.6	
1	83	62	night	8 a. m.	.21	W	.7	
2	80	59	night	10 a. m.	.11	NW	.5	strong wind, showers.
3								
4								
5	81	59	6 p. m.	night	.18	S-SW	.9	strong wind.
6	82	58	—	—	—	W	.5	
7	94	60	—	—	—	NW	.3	

* June 29th. Began raining at 2 p. m. and rained continuously for 48 hours.

† Amounts are not recorded as the writer had no rain-guage with him in 1907.

The next two weeks were very hot and dry but with cool nights. Data were not taken after August 20th. In 1908 the following data were taken at the Cushman vineyard, situated about one mile north of the Raymond vineyard and in much the same position as to exposure and proximity to Cayuga Lake.

METEOROLOGICAL DATA TAKEN AT CUSHMAN VINEYARD, ROMULUS, N. Y., JUNE 8th TO AUG. 18th, 1908.

Date	Temperature		Precipitation			Direction of prevailing wind	Character of day*	Miscellaneous
	Max.	Min.	Time of beginning	Time of ending	Amount			
June 8	94	56	—	—	—	S	.1	
9	91	66	4	6	.73	—	.4	slight shower at 3.30.
10	75	54	—	—	—	W	.4	cloudy in a. m.
11	70	48	—	—	—	NW–NE	.4	very heavy dew.
12	71	44	—	—	—	NE–E	.1	
13	86	50	—	—	—	E–SE	.1	
14	92	63	4 p. m.			S	1.	
15	69	52		5 p. m.	1.67	SW–W	1.	
16	65	51	—	—	—	NW	.1	windy.
17	71	44	—	—	—	NE	.1	heavy dew.
18	84	50	—	—		SE–S	.2	threatening in p. m.
19	94	62	—	—	—	S	.1	threatening in a. m.
20	90	62	—	—	—	W–NW	.1	
21	86	62	—	—	—	N	.1	
22	87	62	night	a. m.	1.25	N	.1	very light wind.
23	88	65	night	a. m.	.25	N	.4	very light wind.
24	89	68	—	—	T†	SW–W	.4	heavy dew, no wind.
25	84	57	—	—	—	W–NW	.3	threatening in a. m.
26	76	50	—	—	—	N–NE	.1	
27								
28								
29			early in a. m.	a. m.	.15	SW–W	.3	
30	81	58	—	—	—	NW		
July 1	87	56	—	—	—	N	.1	
2	86	60	—	—	—	NW–SE	.3	
3	86	62	—	—	—	NE–SE	.1	
4	89	66	4 p. m.	—	T	SE–SW	.3	
5	88	61	—	—	—	SW–W	.1	
6	—	—	—	—	—	NW	.1	
7	95	65	4 p. m.	8 p. m.	.19	SE	.4	
8	79	55	—	—	—	W–NW	.5	cloudy; windy.
9	80	50	—	—	—	NW	.1	
10	98	53	—	—	—	E–SE	.1	
11	95	58	—	—	—	S–SW	.1	
12	92	63	12	6 p. m.	1.05		.5	
13	89	61	night	night	.37	SE	.5	partly cloudy.
14	88	64	8 and 1		T	SW–W	.7	light showers.
15	74	55	—	—	—	W–NW	.2	windy.
16	75	55	—	—	—	NW	.2	
17	71	51	10 a. m.	6 p. m.	.5	SE–S	1.	
18	88	66	8 a. m.	12 m.	.3	SE–S	.8	
19	82	63			T	W–NW	.6	showers.
20	81	57	—	—	—	W	.4	
21	79	57	7 a. m.	night	1.57		1.	
22	88	57			T	W	.4	wind light.
23	82	56	—	—	—	W	.3	wind light.
24	83	60	8 p. m.	night	.47	N	.1	
25	79	64	—	—	—	N	.1	
26	84	60	—	—	—	N	.1	
27	87	56	—	—	—	E	.1	
28	87	60	—	—	—	E	.1	
29	91	61	—	—	—	S	.1	
30	91	63	—	—	—	W	.1	
31	91	60	—	—	—	NW	.1	
Aug. 1	75	55	—	—	—	—	.2	
2	—	51	—	—	—		.1	
3	—	—	—	—	—	—	.1	
4	95	55	—	—	—	SW–N	.4	
5	88	60	night	10 a. m.	.5	S	.8	
6	84	58	—	—	—	SW	.3	heavy dew.
7	79	60	night	night	.6	SW	1.	rainy all day.
8	79	58	—	—	—	N	.4	heavy dew.
9	79	55	—	—	—	N	.2	
10	74	64	—	—	—			
11	81	62	2 p. m.	3 p. m.	T	W	.5	
12	81	58	1 p. m.	2 p. m.	T	S	.5	high wind.
13	88	68	1 and 5 p. m.	2 and 6 p. m.	1.	SW–NE	.7	showers.
14	86	60	—	—	—	W	.2	
15	82	62	—	—	—	NW	.1	
16	—	—	—	—	—	S	.1	
17	88	51	night	8 a. m.	.47	SW		
18	81	59	—	—	—	NW	.1	

* Character of the day, .1–.3 clear; .4–.7 fair or partly cloudy; .8–1. cloudy.
† Trace.

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PLATE I.— *Perithecia of Guignardia bidwellii.*

Unless otherwise noted the photomicrographs have been made with the following combination: Tube length of microscope 160 *mm.; Spencer oc.* 8 *x; obj.* 4 *mm.; distance of plate from object* 39 *cm.*

FIG. 1.— *Perithecia of Guignardia bidwellii with very young asci. Material fixed July* 9, 1907. *Plate* 33 *cm. from object.*

FIG. 2.— *Same as Fig.* 1, *but with Leitz oc.* 4 *and plate* 39 *cm. from object.*

FIG. 3.— *Perithecia slightly older than in Fig.* 2, *but from the same collection.*

FIG. 4.— *Perithecia. One ascus nearly mature; several young uninucleate ones. Material fixed July* 22, 1908.

FIG. 5.— *Perithecia with many mature asci. Material fixed July* 22, 1908.

FIG. 6.— *Perithecium of Guignardia on wintered petiole. Same collection as in Fig.* 18. *Leitz oc.* 4.

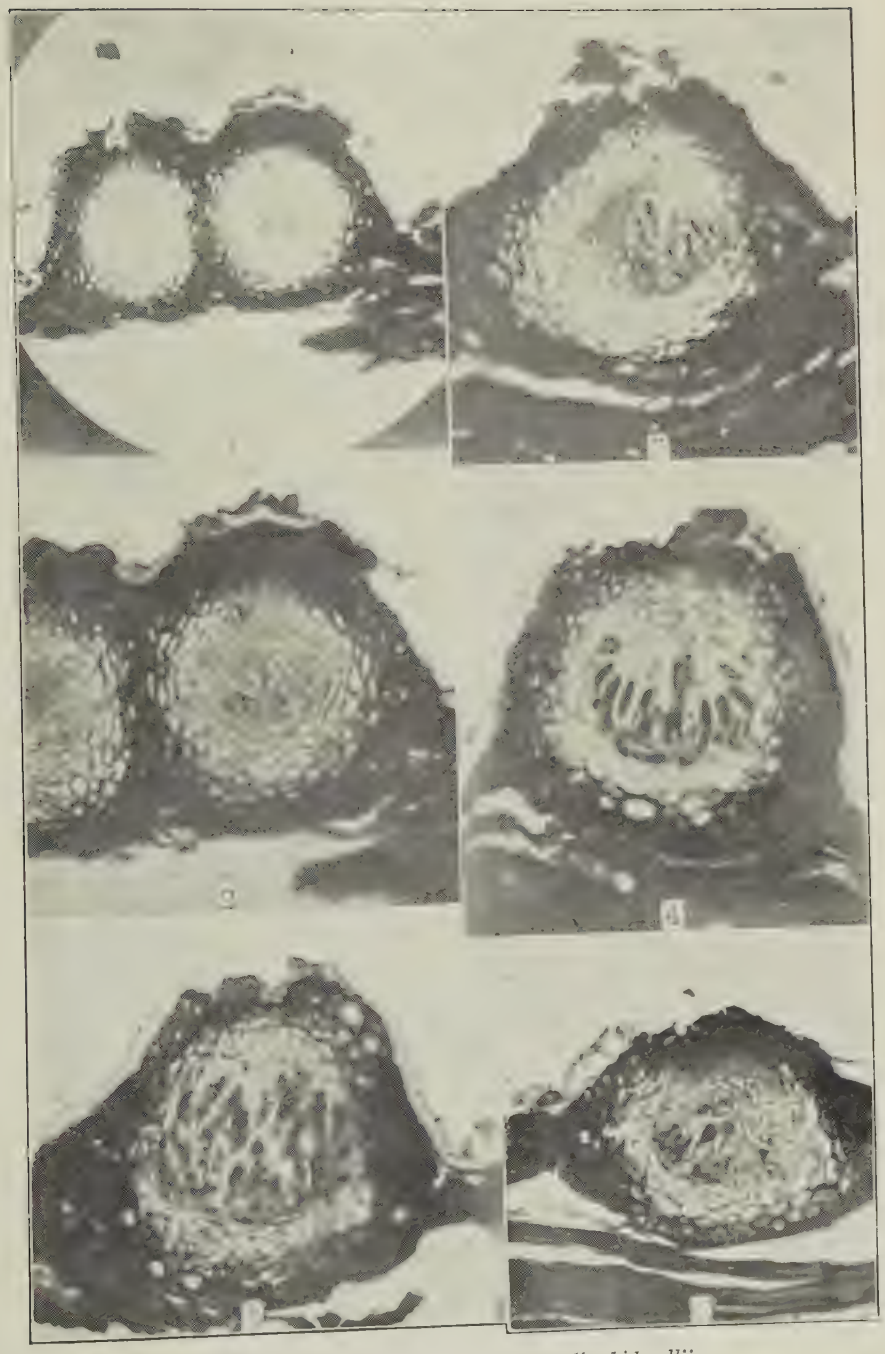

PLATE I.— *Perithecia of Guignardia bidwellii.*

PLATE II.— *Pycnidia and mycelium of Guignardia bidwellii.*

FIG. 7.— *Perithecia and pycnidia on old mummy. Some pycnidia with voided pycnospores. Obj.* 16 *mm. Material fixed July* 22, 1908.

FIG. 8.— *Mycelium of Guignardia just under the epidermis of a grape berry. Material taken Aug.* 14, 1908.

FIG. 9.— *Photomicrograph of a leaf spot showing pycnidia of Guignardia bidwellii. Oc.* 4; *Obj.* 32 *mm.*

FIG. 10.— *Imperfect section of a Black Rot pycnidium. Showing the method of development of pycnospores. Combination of lenses not known.*

FIG. 11.— *Young pycnidium. Material fixed July* 22, 1907.

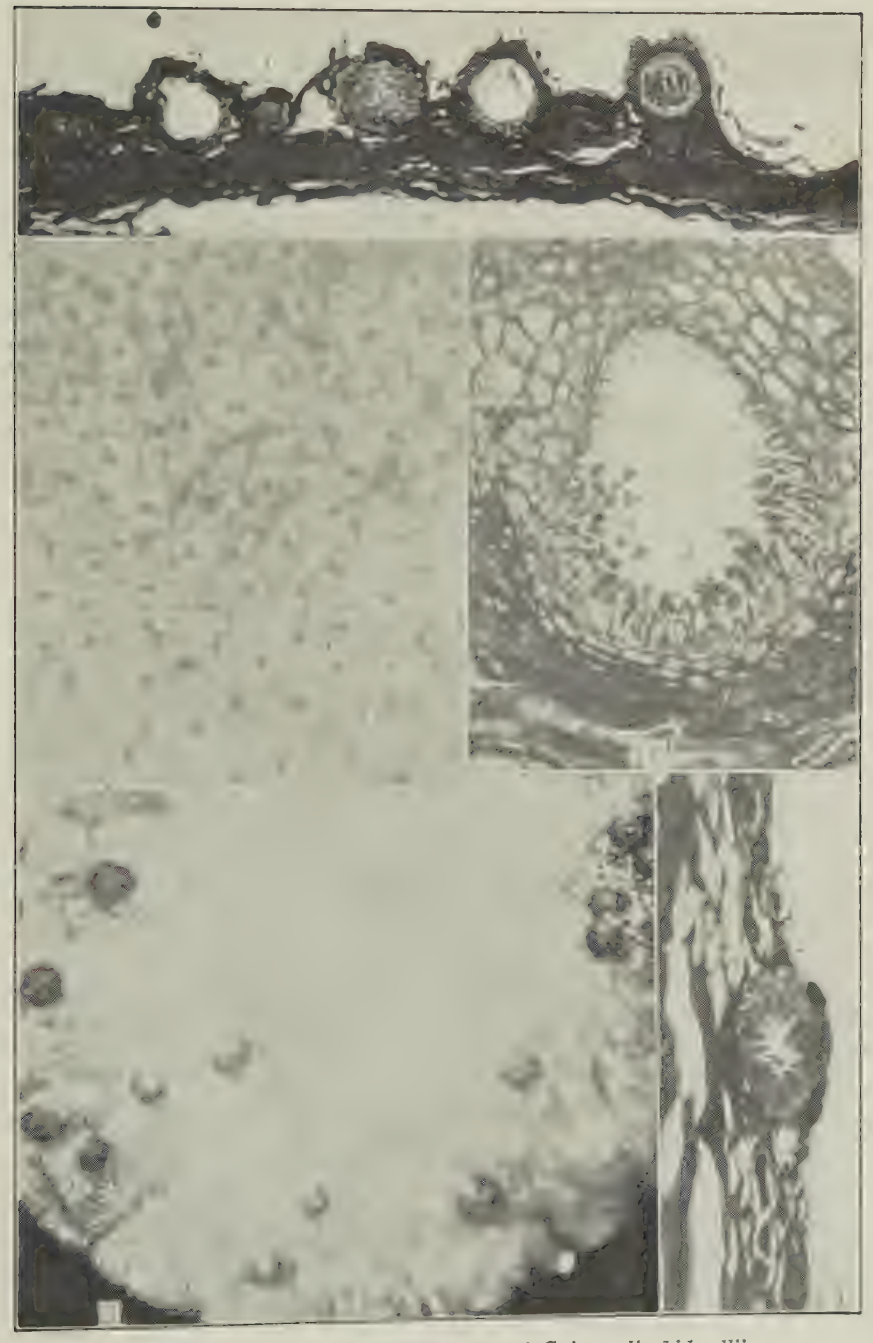

PLATE II.— *Pycnidia and mycelium of Guignardia bidwellii.*

PLATE III.— *Pycnidia of Guignardia bidwellii.*

FIG. 12.— *Young pycnidium of Guignardia on leaf of Niagara grape. Leitz, oc.* 4.

FIG. 13.— *Young pycnidium on fruit of Niagara grape. Material fixed July* 22, 1907.

FIG. 14.— *Pycnidium of Black Rot fungus on a wintered leaf petiole. Leitz. oc.* 4; *obj.* 16. *Material fixed June* 24, 1908.

FIG. 15.— *Same as fig.* 14, *but with obj.* 4.

FIG. 16.— *Pycnidium from green shoot. Material fixed June* 13, 1908.

FIG. 17.—*Pycnidium containing pycnospores and spermatia. Pycnosclerotium on the left. Material fixed Oct.* 5, 1907.

FIG. 18.— *Pycnidium from wintered mummy. Note the binucleate pycnospores.*

FIG. 19.—*Section of a spermogonium. Material taken July* 23, 1908.

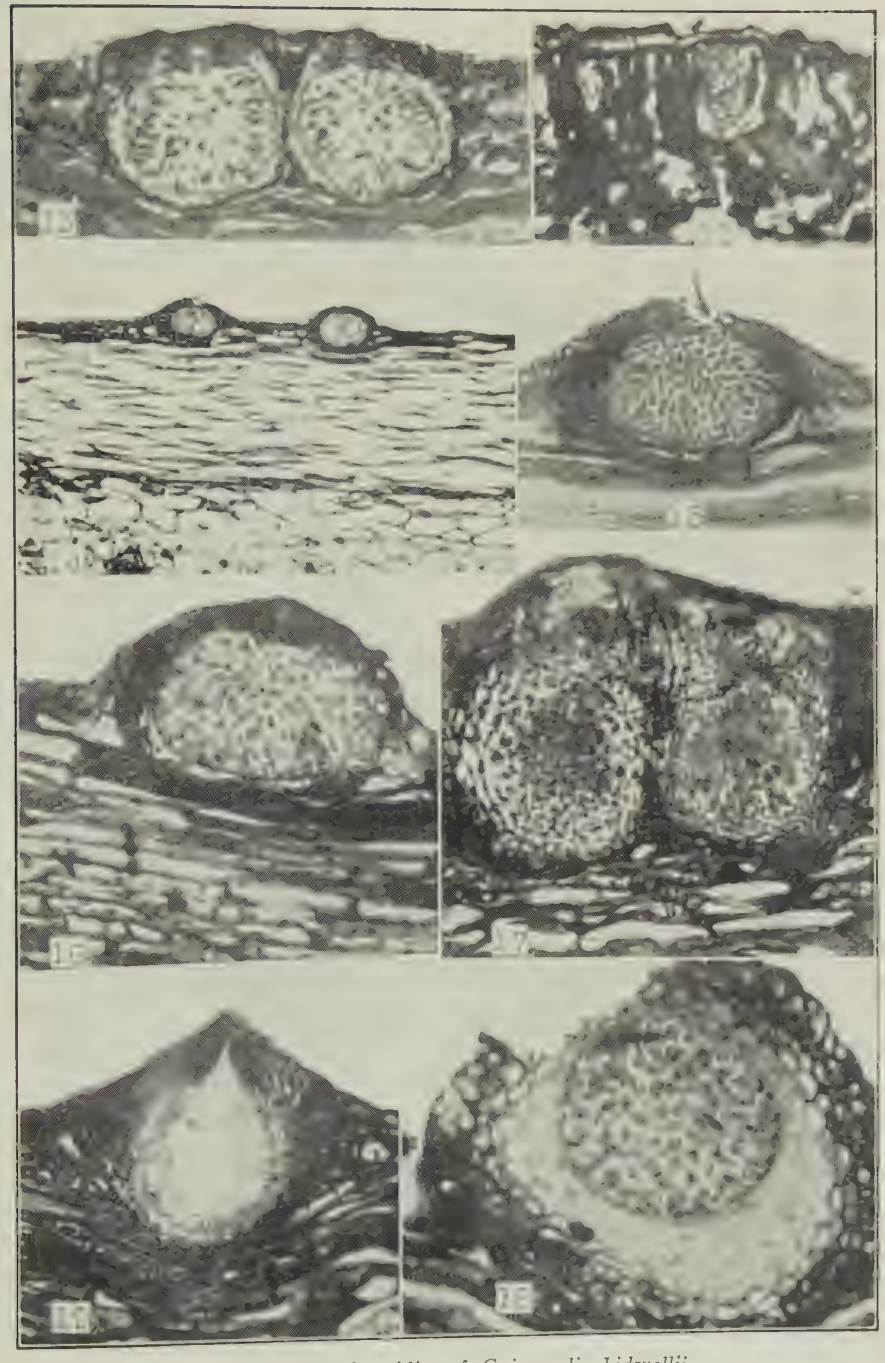

PLATE III.—*Pycnidia of Guignardia bidwellii.*

PLATE IV.— *Pycnosclerotia and spermogonia of Guignardia bidwellii.*

FIG. 20.— *Histological changes in structure of a stem bearing a lesion of the Black Rot fungus. Both healthy and diseased tissue shown. Obj.* 16 *mm. Material fixed June* 13, 1908.

FIG. 21.— *Spermogonium of Fig.* 22. *Plate to object* 39 *cm.*

FIG. 22.— *Pycnosclerotium and spermogonium of Guignardia. Berries began to show spots July* 17, 1908, *and were dropped into fixer July* 23. *Pycnospores have never been developed in these conceptacles. Distance from plate to object* 33 *mm.*

FIG. 23.— *Pycnosclerotium of Fig.* 22. *Plate to object* 39 *cm.*

FIG. 24.— *"Conidia." Pycnosclerotium with hyphae about ostiole. Kept in moist chamber a few days. Material fixed July* 10, 1908.

FIG. 25.— *Cross-section of a spermogonium. Also shows mycelium well. Material fixed July* 23, 1908.

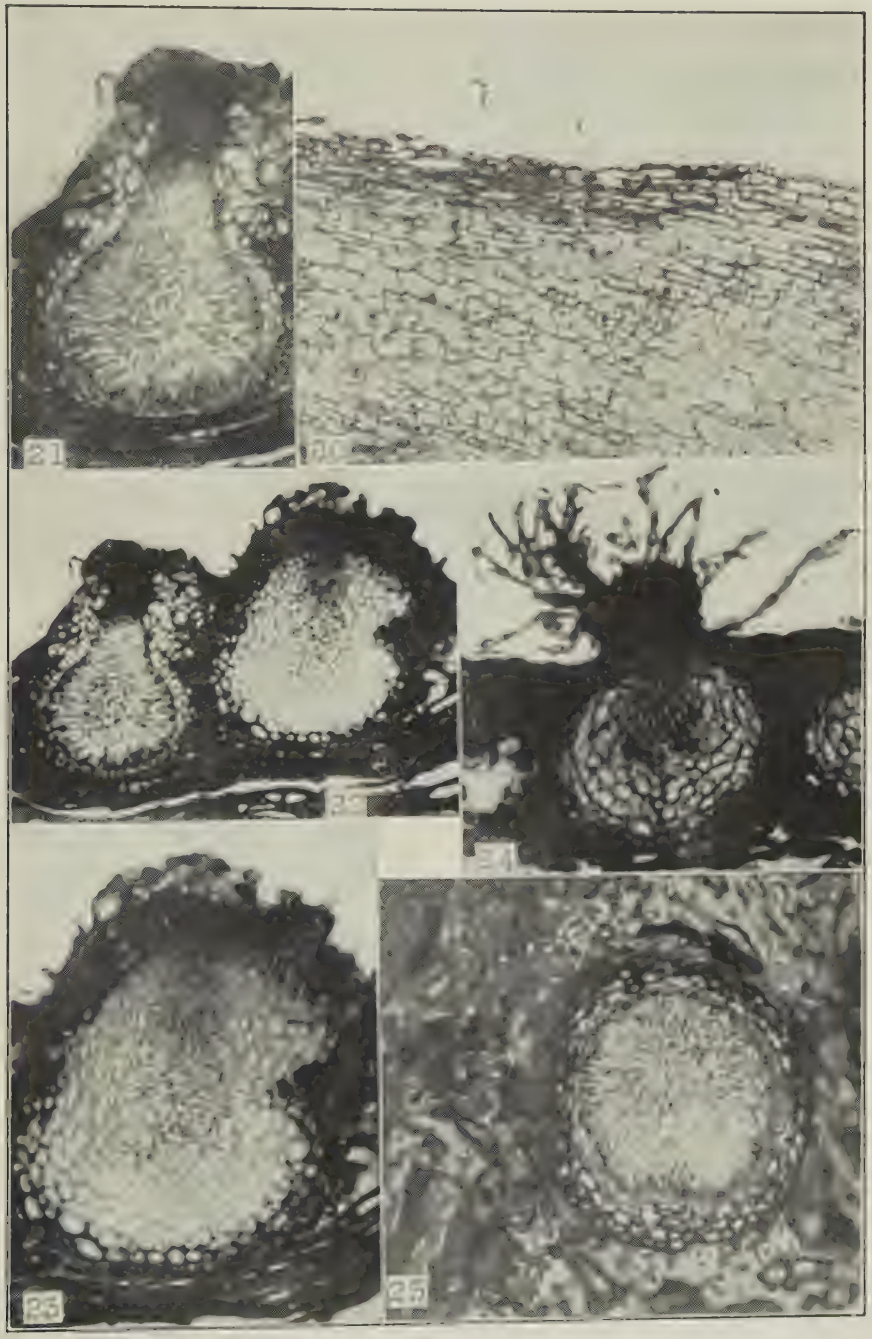

PLATE IV.—*Pycnosclerotia and Spermogonia of Guignardia bidwellii.*

PLATE V.— *Spores of Guignardia bidwellii.*

Unless otherwise noted the following combinations have been used. Leitz oc. 4, obj. 1/16, *tube* 120 *mm. Camera lucida with arm* 120 *mm. and mirror at* 45°. *Paper on the table. Reduced one-third in reproduction.*

FIG. 26.— *Nearly mature ascus with spores. Ascus somewhat elongated by absorption of water, July* 4, 1907. *Wall should appear thickened. The faint line used to show the limits was lost in reproduction. With the microscope it can be seen only by careful focusing.*

FIG. 27.— *Fully mature ascospores. Showing the hyaline appendage. July* 4, 1907.

FIG. 28.— *Germinating ascospores.* 48 *hours. July* 26, 1907.

FIG. 29.— *Germinated ascospores with appressoria.*

FIG. 30.— *Pycnospores from stem lesions. Aug.* 1, 1907.

FIG. 31.— *Pycnospores from black rotted fruit. Aug.* 1, 1907.

FIG. 32.— *Pycnospores from leaf spots. Aug.* 1, 1907.

FIG. 33.— *Pycnospores germinated. Twelve hours in a drop of water on the surface of a berry. July* 17, 1908.

FIG. 34.— *Germinated pycnospores* (20 *hours*) *from an old mummy. June* 25, 1907.

FIG. 35.— *Germinated pycnospores. Oc.* 4 *mm.; obj.* 1/6.

FIG. 36.— *Germinating pycnospores with appressoria. Oc.* 4 *mm.; obj.* 1/6.

FIG. 37.— *Spermatia. oc.* 4 *mm. obj.* 1/12. *Aug.* 19, 1907.

FIG. 38.— *"Conidia" from perithecium. June* 28, 1909. *Oc.* 8 *x; obj.* 4 *mm.; tube* 160 *mm.*

FIG. 39.— *Camera lucida drawing from a microtome section of a Black Rot lesion on leaf. Showing the effect on the spongy parenchyma. Leitz oc.* 2 *mm. Spencer obj.* 4 *mm. tube* 160 *mm. arm of camera lucida* 120. *Paper on level with stand.*

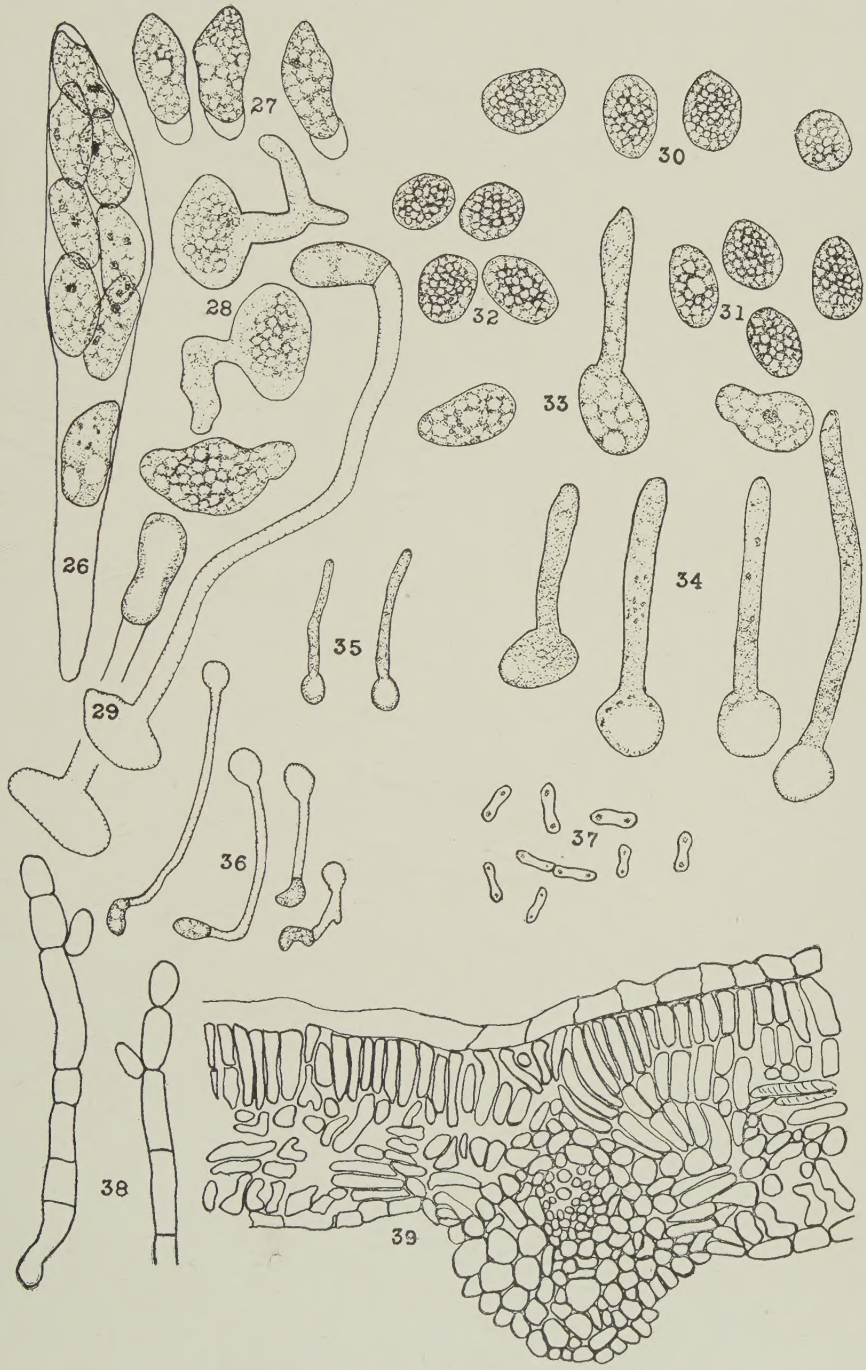

PLATE V.—*Spores of Guignardia bidwellii.*